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BULLETIN OF THE U.S. DEPARTMENT OF AGRICULTURE

No. 151

Contribution from the Bureau of Plant Industry, Wm. A. Taylor, Chief.
September 19, 1914.

EXPERIMENTS IN CROP PRODUCTION ON FALLOW LAND AT SAN ANTONIO.[1]

By C. R. Letteer, *Assistant, Office of Western Irrigation Agriculture.*

INTRODUCTION.

The practice of fallowing land varies widely in different regions. In the experiments conducted at San Antonio, Tex., and reported in this paper the word "fallow" is used to mean thorough cultivation of the land from the time it is plowed after the removal of a crop throughout the next season and until the crop is planted at the beginning of the second season. The fallow period at San Antonio varies from 16 to 19 months, depending on the crops grown. The chief ostensible purpose of fallowing in this region is to store in the soil for the benefit of the next crop the moisture which falls during the fallow period.

In order to determine whether or not this practice is to be recommended in the San Antonio region, the experiments reported herein were started in 1910.

CLIMATIC CONDITIONS.

The climatic conditions at San Antonio are much different from those in the dry-farming regions farther north.

The conditions fluctuate irregularly from semiarid to humid. Droughts of many weeks' duration are common and may come at almost any season of the year, but they are more frequent and more serious during the summer months. The mean annual rainfall at San Antonio for a period of 33 years, as reported by the United States Weather Bureau, is 26.83 inches. The mean annual rainfall for the 7-year period from 1907 to 1913, inclusive, as measured at the San Antonio Experiment Farm, 5 miles south of the city, is 24.66 inches. While the normal precipitation would appear to be sufficiently large to make crop production fairly certain, yet on account of the unequal distribution of the rainfall and the high

[1] From January, 1910, to October, 1911, the experiments here reported were under the direct supervision of Mr. S. H. Hastings, superintendent of the San Antonio Experiment Farm. Mr. C. R. Letteer has had direct charge of the work since October, 1911.

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evaporation the effect of the precipitation is much lessened. The mean annual evaporation from a free water surface, as measured at the experiment farm for the 7-year period specified, is 65.88 inches.

The winters are mild, yet periods of cold weather or "northers" are not infrequent during the winter season. The thermometer seldom registers a temperature below 15° F. in winter, and consequently plant growth continues practically throughout the year.

SOIL CONDITIONS.

The San Antonio Experiment Farm is located on what is called locally black "hog-wallow land." This local name is due to the fact that the soil, when drying, shrinks and opens long, wide cracks, and the filling of these cracks with loose surface soil results in irregular depressions, which resemble hog wallows. The soil is a black clay loam, having a rather small proportion of sand and becoming very sticky when wet. It is classified by the United States Bureau of Soils [1] as Houston black clay loam and San Antonio clay loam.

The first 3 feet of soil is fairly uniform in character and is underlain with a white gravelly material which is rich in lime. This underlying gravel has a relatively low moisture-holding capacity, while the surface soil has a high moisture-holding capacity, averaging from 25 to 30 per cent. When wet, the soil has a tendency to pack and become impervious, so that during torrential rains the loss of water from run-off is high. The soil is rich in mineral plant food and produces abundant crops when supplied with sufficient moisture.

FALLOWING EXPERIMENTS.

In 1910 experiments were inaugurated for the purpose of studying the effect of producing a crop only on alternate years, as compared with producing a crop every year on the same land. The crops of 1910 were grown on land which had not been previously fallowed, so that the results for that year are not considered here. The results here presented are from the years 1911, 1912, and 1913.

The crops used in these experiments were corn, cotton, and winter oats. For this purpose six $\frac{1}{4}$-acre plats were used, as follows: Plats A4–1 and A4–2 were used alternately for cotton, one plat being cropped and the other fallowed each year. In a similar way plats A4–3 and A4–4 were used for corn and A4–5 and A4–6 for winter oats. For purposes of comparison with these biennially cropped plats, use has been made of results obtained from three plats which are part of another experiment. These three plats are cropped each year and are given the same tillage treatment as the alternately cropped plats, except that the fallow period is 12 months shorter. The plats that are cropped annually have been under test since 1909, when the large

[1] Field Operations of the Bureau of Soils, 1904.

rotation and tillage experiment of which they are a part was started. The plats which are continuously cropped are as follows: B5–1, corn; B5–3, cotton; and B5–8, oats. The plats are each 264 feet long and 41.25 feet wide, and they are separated by alleys 4¾ feet wide.

TREATMENT OF THE PLATS.

Figure 1 shows graphically the cropping system practiced on the plats considered in this report, from the time the biennial cropping experiments were started until the close of the year 1913.

The winter oats were seeded early in November and harvested in May, the corn was planted the latter part of February and harvested

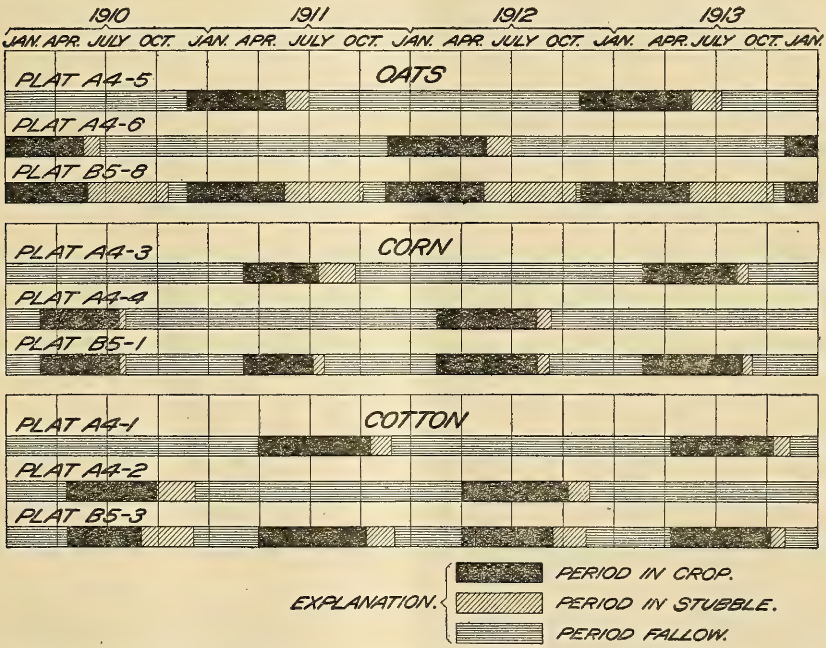

FIG. 1.—Diagram showing the cropping system practiced on the plats where biennial cropping has been tested in comparison with continuous cropping at the San Antonio Experiment Farm.

in July, and the cotton was planted early in April and the harvest completed in October.

In all cases except plat B5–8 (oats cropped annually) the plats were plowed about 8 inches deep as soon as practicable after the crop was removed. Plat B5–8 was left unplowed until just before planting time. After plowing, the plats were harrowed after the first heavy rain came, to soften the clods. They were then harrowed or disked after each rain of consequence and also whenever it was necessary to keep them clear of weed growth and to maintain a soil mulch. For the most part the spike-tooth harrow was sufficient to maintain an adequate mulch throughout the greater part of the fallow period.

YIELDS OBTAINED.

Table I gives the yields of various crops from the plats cropped biennially, as compared with the yields of the same crops on plats cropped annually, and the average yields of the various crops from all plats planted to each crop in the rotation experiments. The average yields are obtained by considering all of the plats in the rotation experiments and should be fairly representative of results from good farming in that region.

TABLE I.—*Crop yields from plats cropped biennially, as compared with plats cropped annually and with all plats used for these crops in the rotation experiments.*[1]

Year and crop.	Biennial cropping.		Annual cropping.	Average of all rotation plats.	
	Actual.	Percentage of annual cropping.		Yield.	Number of plats averaged.
1911.					
Corn .... bushels..	3.2	59.2	5.4	10.6	29
Cotton .... pounds..	318.0	71.3	446.0	483.0	25
Oats .... bushels..	10.1	160.5	6.3	8.5	11
1912.					
Corn .... bushels..	24.7	92.9	26.6	34.1	26
Cotton .... pounds..	448.0	94.6	474.0	621.5	25
Oats .... bushels..	37.0	181.5	20.4	26.75	10
1913.					
Corn .... bushels..	30.7	92.8	33.1	34.9	21
Cotton .... pounds..	350.0	53.9	508.0	560.1	30
Oats .... bushels..	38.0	369.0	10.3	11.7	9
AVERAGE, 1911–1913.					
Corn .... bushels..	19.5	89.9	21.7	26.5	....
Cotton .... pounds..	372.0	78.2	476.0	554.9	....
Oats .... bushels..	28.4	231.0	12.3	15.7	....

[1] The rotation experiments are conducted on 82 quarter-acre plats. They include continuous cropping, biennial cropping, and 2-year, 3-year, and 4-year rotations, combined with various tillage methods, manuring, and green manuring. In general, it would be expected that the average yields in these experiments would be larger than those obtained from the continuously cropped plats.

It is shown in Table I that in no instance has cotton or corn yielded as much on biennially cropped as on annually cropped land. The average yields of cotton and corn on all the rotation plats have been higher than those secured from either biennial cropping or annual cropping, indicating that neither fallowing nor continuous cropping for corn and cotton is to be recommended as a general practice under San Antonio conditions.

On the other hand, winter oats on land biennially cropped have consistently yielded higher than where planted annually on the same land and higher than the average from all oat plats in the rotation experiments.

VEGETATIVE GROWTH OF CROPS ON FALLOWED LAND.

It has been observed during the past two years that during the greater part of the growing period oats made a less rank growth on the fallowed plat than on the plats in the rotation experiments.

This comparatively light vegetative growth appears to have been favorable to the production of grain. In 1912 and 1913, especially the latter season, oats on the rotation plats lodged badly, owing to excessive vegetative growth. It has been found at San Antonio that any treatment which has a tendency to retard the early vegetative growth of the oat plant results in increased yields of grain. An instance substantiating this statement is afforded by the unfavorable results from manuring on land planted to oats to be harvested for grain. In a 4-year test with oats, manuring has noticeably decreased the yield of grain in two out of the four years, while in the other two years the yields were practically the same as those obtained from unmanured land. It appears, therefore, that the increase in yield of oats on fallowed land has not been due to the fact that conditions were more favorable to growth, but rather to a depressing effect on the vegetative growth.

Crops grown on fallowed land have invariably shown irregular and slow early development as compared with the same crops on other plats. The corn and cotton on the fallowed plats have been noticeably smaller than on the other plats in the rotation experiments, and the plants have lacked uniformity in size and appearance. Observations on other plats of the experiment farm where cotton has been grown on fallowed land corroborate this conclusion. While the differences with oats have not been so marked, in 1913 the oats on fallowed land were smaller and made slower growth than on land continuously cropped or having other treatments. On account of the difficulty with the lodging of grain crops, as already indicated, the depressing effect of fallowing on the growth of the plants results in high yields of oats, while it has the opposite effect on corn and cotton.

SOIL-MOISTURE STUDIES.

Soil-moisture determinations have been made on the fallowed plats considered in this report and also on the continuously cropped plats devoted to the same crops. Samples have been taken monthly or oftener during the summer throughout the three years. A standard soil tube was used for securing the samples. At each sampling two cores were taken from different parts of the plat, corresponding foot-sections being composited to a single sample. Thus either three or six samples were secured from each plat, depending upon the depth to which the sampling was done. In most cases samples were taken to a depth of 6 feet.

In figures 2, 3, and 4 the diagram at the top shows the crop, stubble, and fallow periods for each plat considered in this report, and the curves below show the moisture content of the different plats at the time the moisture determinations were made during the four years from 1910 to 1913, inclusive.

Moisture determinations have been made on each of the plats at planting time and just before or just after harvest, to determine the

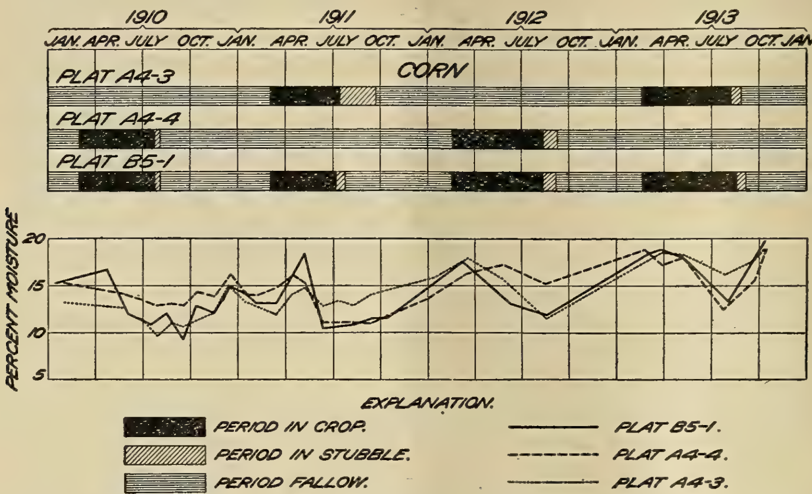

FIG. 2.—Diagram showing the average moisture content of the soil on plat B5–1, which was cropped annually to corn, and on plats A4–3 and A4–4, which were cropped biennially to corn, at the San Antonio Experiment Farm, January, 1910, to October, 1913. On each sampling date all the plats were sampled to a uniform depth, in most cases 6 feet, but in some instances 3 feet.

amount of moisture present at planting time and the amount of stored moisture used from each plat.

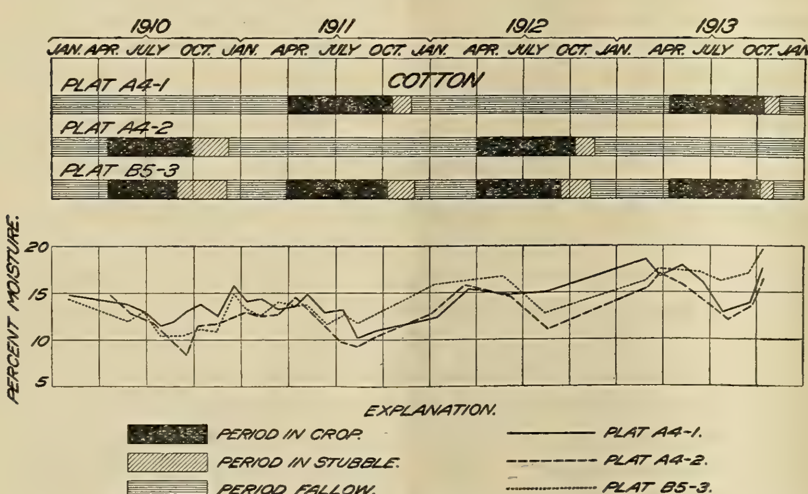

FIG. 3.—Diagram showing the average moisture content of the soil on plat B5–3, which was cropped annually to cotton, and on plats A4–1 and A4–2, which were cropped biennially to cotton, at the San Antonio Experiment Farm, January, 1910, to October, 1913. On each sampling date all the plats were sampled to a uniform depth, in most cases 6 feet, but in some instances 3 feet.

By observing carefully the curves showing the moisture content in the various plats it will be seen that the moisture content of the

plats of corn (fig. 2) and cotton (fig. 3) was generally highest in the spring at about planting time for these crops; that there was a general decline in the moisture content of the cropped plats until harvest and also a slight decline in the moisture content of fallowed plats; and that there was only a slight difference in the moisture content of the fallowed and continuously cropped plats at either planting or harvest time, the tendency being for the curves to coincide at these periods.

The moisture content of the oat plats (fig. 4) was generally highest during the months of January and February and lowest in June, at about harvest time. At planting time for oats in the autumns of

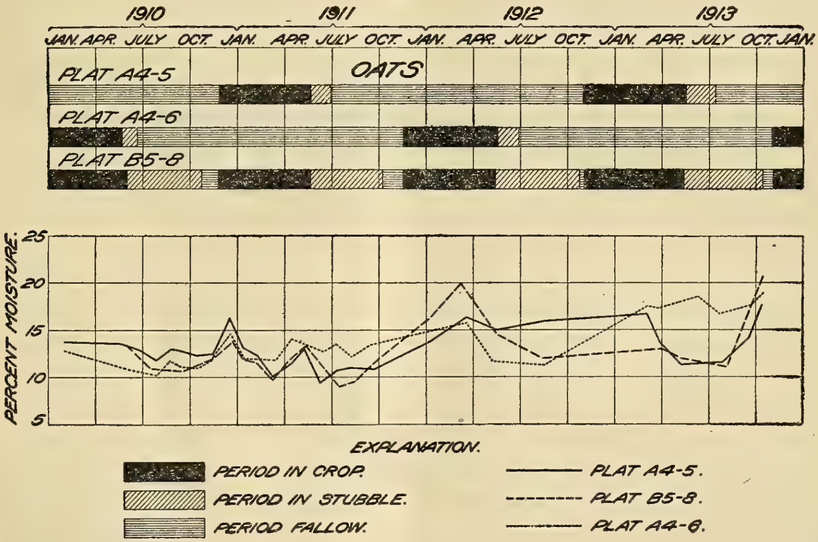

FIG. 4.—Diagram showing the average moisture content of the soil on plat B5–8, which was cropped annually to oats, and on plats A4–5 and A4–6, which were cropped biennially to oats, at the San Antonio Experiment Farm, January, 1910, to October, 1913. On each sampling date all the plats were sampled to a uniform depth, in most cases 6 feet, but in some instances 3 feet.

1910 and 1912 the moisture content of the fallowed plat was somewhat higher than that of the continuously cropped plat, and in 1911 it was nearly the same. At harvest time in 1911 and also in 1912 the moisture content of the fallowed plat was somewhat lower than that of the continuously cropped plat, and in 1913 the moisture content of both plats was about the same.

It appears from this that fallowing resulted in a higher moisture content in the fall at planting time for oats, and that when the land remained fallow until time for planting corn and cotton, fallowing did not store any appreciable quantity of moisture in the soil in excess of that stored in land continuously cropped, plowed in the fall, and left fallow during the winter.

For the most part the curves show only slight variations in the amount of moisture present in the fallowed and continuously cropped plats during the period when crops were on the land. There was a somewhat higher moisture content in the soil of the fallow plats at the time when crops were growing on the other plats; but, as already stated, the difference generally disappeared by the next planting time.

RUN-OFF FROM FALLOWED PLATS.

The uniformity in soil-moisture content at planting time, already noted, is probably accounted for by the higher loss by run-off from fallow plats than from those which were cropped every year. During the years covered by this report the precipitation during the winter and early spring was comparatively heavy. Consequently, so far as the rainfall during the winter and spring immediately preceding corn and cotton planting was concerned, land cropped each year and plowed as soon as possible after the removal of the crop had the same opportunity to store moisture as fallowed land had during the same period. Even though the fallowed land contained a larger amount of moisture at the time of seeding oats in the fall, a larger amount of run-off from the fallowed plats during the winter would result in approximately uniform moisture conditions in all the plats at the time of planting corn and cotton the following spring. That there is a difference in the run-off from the different plats is proved by the results of determinations shown in Table II.

On February 16, 1912, three days after a rain of 3.3 inches, soil samples were taken on one plat of oats and on five fallow plats where the length of time since plowing varied from 3 to 18 months. Table II shows the moisture content at the last sampling before the rain and again three days after the rain, together with the increase in moisture, the run-off in inches, and the percentage of rainfall lost by run-off.

On February 26, samples were again taken on the same plats after a 2-days' rain of 2.9 inches. The results are also given in Table II.

TABLE II.—*Absorption and run-off from rains in February, 1912, San Antonio Experiment Farm.*

Plat No.	Fallow period or crop.	Samples taken on Feb. 16, three days after a 3.3-inch rain.					
		Average moisture content in 3 feet.		Increase.		Run-off.	
		5 days before rain.	3 days after rain.	Per cent.	Inches.	Inches.	Percentage of rainfall.
		Per cent.	*Per cent.*				
A4-1	3 months	15.8	19.9	4.1	1.92	1.38	41.8
A4-2	15 months	19.1	21.6	2.5	1.17	2.13	64.5
A4-3	5 months	17.2	19.8	2.6	1.22	2.08	63.0
A4-4	18 months	20.0	23.0	3.0	1.40	1.90	57.5
A4-5	6 months	18.4	20.6	2.2	1.03	2.27	68.8
A4-6	Oats	18.1	22.3	4.2	1.96	1.34	40.6

TABLE II.—*Absorption and run-off from rains in February, 1912, San Antonio Experiment Farm*—Continued.

Plat No.	Fallow period or crop.	Samples taken on Feb. 26, one day after a 2.9-inch rain, when the soil was already wet.					
		Average moisture content in 6 feet.		Increase.		Run-off.	
		7 days before rain.	1 day after rain.	Per cent.	Inches.	Inches.	Percentage of rainfall.
		Per cent.	*Per cent.*				
A4-1	3 months	15.2	16.6	1.4	1.3	1.61	55.3
A4-2	15 months	16.8	17.2	.4	.37	2.54	87.1
A4-3	5 months	15.3	16.8	1.5	1.4	1.51	51.7
A4-4	18 months	16.7	17.8	1.1	1.03	1.88	64.6
A4-5	6 months	15.5	16.2	.7	.66	2.25	77.3
A4-6	Oats	16.3	18.4	2.1	1.96	.95	32.6

Table II shows that the run-off from land that had been fallow for several months was greater than from land plowed a comparatively short time before the heavy rains. The proportion of run-off from the second rain was somewhat greater than that following the first rain, and the difference in run-off from plats fallowed for a short time and from those which had been fallow for a longer time was more marked. The run-off from the oat plat was materially less following both rains than that from any of the fallow plats.

ECONOMIC CONSIDERATIONS.

The question of whether it is desirable to make a practice of biennial cropping for certain crops must be considered from two standpoints: (1) The effect upon the crop and (2) the cost of production as compared with annual cropping. It must be remembered that in the first case only one crop is grown in two years and that fixed costs, such as the interest on the investment in land for two years, must be charged against one crop. Under the conditions at San Antonio, where plant growth continues practically the entire year, making necessary the cultivation of the fallow to kill weeds and maintain a mulch, the expense of fallowing is nearly, if not quite, as much as that of growing a crop on the land. Other items, such as the depletion of the humus and the possible ultimate effect on fertility, are matters deserving consideration in connection with the practice of biennial cropping. It must be concluded, then, that even though biennial cropping gave increased yields of winter oats at San Antonio it is not necessarily desirable as a farm practice in growing that crop there. In other words, the results of these experiments indicate that biennial cropping is not to be recommended for the San Antonio region, at least for cotton, corn, and oats.

SUMMARY.

(1) Tests of biennial cropping in comparison with annual cropping have been carried on at the San Antonio Experiment Farm for three years.

(2) The yields of corn and cotton have been less on biennially cropped land than on annually cropped land. The yields of winter oats have been somewhat larger on the biennially cropped land.

(3) Soil-moisture studies made in connection with these tests do not show any important differences in the amount of soil moisture present in fallowed land and in continuously cropped land at planting and harvest time for corn and cotton. In the plats used for oats there was more moisture present at planting and less at harvest time on the biennially cropped land than on the annually cropped land. In other words, the oats grown biennially used more water and made less vegetative growth, but gave larger yields.

(4) Observations made after heavy rains show that in most cases the proportion of run-off from heavy rains was greater on land which had been fallow for several months than on land which had been fallow for a comparatively short time. The run-off from an oat plat was less than from any of the fallow plats.

(5) Considering both crop yields and cost of production, the results of these experiments indicate that biennial cropping, at least for corn, cotton, and oats, is not to be recommended for the San Antonio region.

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BULLETIN OF THE
U.S. DEPARTMENT OF AGRICULTURE

No. 152

Contribution from the Forest Service, Henry S. Graves, Forester.
February 3, 1915.

THE EASTERN HEMLOCK.[1]

(*Tsuga canadensis* (Linn.) Carr.)

By E. H. Frothingham, *Forest Examiner.*

CONTENTS.

INTRODUCTION.

Though excelled in most respects by other trees in the region of its growth, eastern hemlock is none the less a most important member of the remaining old-growth forests. Its lumber, once held nearly worthless, now serves many purposes for which pine was formerly demanded; its wood supplies more raw material for paper pulp than does any other in the United States except spruce, while the amount of its bark used for tanning exceeds that of all other native species combined. Compared with pine, hemlock has been lumbered for only a short time, but this exploitation, accompanied as it has often been by waste and fire, has already greatly reduced the supply of standing timber. If the present rate of cutting continues hemlock will before very long be as scarce as old-growth pine.

In spite of its present importance, hemlock is not a tree of promise for forest planting. White and red pine will yield better lumber in a much shorter time and on poorer soils, are less suceptible to decay, and are more easily grown. Spruce serves as well for the protection of watersheds and stream sources, and produces better pulpwood

[1] There are two species of hemlock in the eastern United States, but one—*Tsuga caroliniana* Engelm.—is restricted to the Southern Appalachians, and is of only local importance. This bulletin treats only of the other species—*Tsuga canadensis* (Linn.) Carr.

Note.—This bulletin describes the more important characteristics of hemlock, presents tables of its volume and rate of growth, and gives the chief facts regarding its utilization. Acknowledgment is due to Messrs. E. M. Griffith, State Forester of Wisconsin, and R. S. Kellogg, Secretary of the National Lumber Manufacturers Association, for assistance rendered in the field study and in the course of preparation of this bulletin.

and lumber. Several other species produce fully as good tan bark or extract in a shorter time. Nevertheless hemlock will undoubtedly persist in the old-growth forests and natural second-growth in many

FIG. 1.—Botanical distribution of hemlock.

regions, and its presence in these stands may be of decided benefit to them. For this reason it must be considered in forest management.

GEOGRAPHICAL RANGE.

Hemlock finds its home in the white pine region of eastern North America. This also is the region inhabited by the characteristic

beech-birch-maple forest—the "northern hardwoods"—of which hemlock is often a conspicuous member. The tree's northern limit corresponds roughly with the forty-seventh parallel of latitude, from Nova Scotia to east central Minnesota (Carlton, St. Louis, and Aitkin Counties, and the St. Croix River), whence it extends south to central Wisconsin, southern Indiana (Floyd County), central Ohio, and northwestern Delaware. It is important in the mountainous portions of New England, New York, and Pennsylvania, and extends along the Appalachian Mountains, through western Maryland, eastern West Virginia, southwestern Virginia, eastern Kentucky and Tennessee, and western North and South Carolina, into northern Georgia and Alabama. It grows neither so far north nor so high in the mountains as the eastern spruces and firs,[1] and reaches its greatest size in the coves of the mountains of western North Carolina and eastern Tennessee.

COMMERCIAL RANGE.

About two-thirds of the total cut of eastern hemlock lumber comes from Wisconsin, Michigan, and Pennsylvania, in the order named, with West Virginia, New York, and Maine following. The other States within its range aggregate about 11 per cent. The shifting of the relative importance of different States in hemlock production within recent years is shown in Table 1, based on data collected by the Census Bureau and the Forest Service.

TABLE 1.—*Hemlock lumber cut in different States, in per cent of the total cut of hemlock, and rank of States in order of production.*

[From United States Census reports for 1899, 1904, and 1906–1912.]

State.	1913		1911		1909		1907		1899	
	Proportion of total cut.	Rank.	Proportion of total cut.	Rank.	Proportion of total cut.	Rank.	Proportion of total cut.	Rank.	Proportion of total cut.	Rank.
	Per cent.		*Per cent.*		*Per cent.*		*Per cent.*		*Per cent.*	
United States	100	......	100	......	100	......	100	......	100	......
Wisconsin	28.7	1	26.6	1	23.2	1	23.3	2	11.7	3
Michigan	19.0	2	21.8	2	20.1	3	20.4	3	24.6	2
Pennsylvania	14.2	3	18.2	3	22.5	2	25.2	1	45.6	1
West Virginia	8.9	4	10.3	4	9.2	4	8.0	4	2.5	5
New York	5.3	5	5.0	5	5.3	5	6.1	5	8.9	4
Maine	3.1	6	3.3	6	3.6	6	3.6	6	2.5	6
Tennessee	1.8	7	1.4	9	1.2	11	1.2	9	......	18
North Carolina	1.6	8	......	......	1.3	10	.9	11	......	16
Vermont	1.3	9	1.5	8	2.0	8	2.2	8	1.2	8
New Hampshire	1.3	10	1.5	7	2.2	7	2.6	7	1.3	7
Virginia	......	......	1.2	10	1.4	9	1.1	10	......	15
Massachusetts	......	......	1.0	11	.8	13	.8	13	.4	10
Kentucky	......	......	......	......	.9	12	.8	12	.1	12
Maryland	......	......	......	......	.7	14	.7	14	.6	9
States producing western hemlock	12.2	......	7.0	......	4.2	......	2.1	......	.02	......
All other States	2.6	......	1.2	......	1.4	......	1.0	......	.58	......

[1] Hemlock is not found where the average temperature during the four growing months is less than 55° F., and but seldom where the average is below 58°. (For. Quart., Vol. XI, No. 1, pp. 64–66, "Northern Limits of East Canadian Trees in Relation to the Climate," by H. R. Christie.)

AMOUNT OF STANDING TIMBER.

Reliable estimates of the amount of standing hemlock are very difficult to obtain, because of the widely varying proportion which the tree forms of the mixed forests in which is usually grows. For this reason past estimates have been greatly at variance with one another. Thus the total stand was estimated to be 20,165 million board feet in 1880 by C. S. Sargent; 56,571 million board feet in 1903 by R. A. Long; 100 billion board feet in 1905 by the American Lumberman; and 75 billion in 1909 by R. S. Kellogg. In 1880 Sargent estimated the amounts of standing hemlock in Pennsylvania, New York, and New Hampshire to be 4½ billion, 3 billion, and 165 million board feet, respectively. The stand in Pennsylvania was estimated to be 5 billion board feet in 1896 by Dr. B. E. Fernow, and 10 billion board feet in 1907 by J. E. Defebaugh.

By far the most careful estimates are those for the Lake States prepared by the Bureau of Corporations in 1910.[1] According to these the amount of standing hemlock in the Lake States is 26.6 billion board feet, of which Michigan has 15 billion and Wisconsin 11.6 billion. Hemlock comprises 34.6 per cent of all the standing timber in both States—31.5 per cent of that in Michigan, and 39.7 per cent of that in Wisconsin. Compared with these estimates the production of hemlock lumber in Michigan and Wisconsin during 1909 represented 4.1 per cent and 6.1 per cent, respectively, of the total stand. For all species combined this relation was 4 per cent and 6.9 per cent, respectively, which makes it evident that the cutting of hemlock proceeds at a rate very close to the average for all species—more rapid than for hardwoods and much slower than for pine.

Hemlock may form a very small or a very large proportion of the forest, while between these extremes are all gradations. One of the largest remaining stands of hemlock in the Lake States is on the Menominee Indian Reservation. The total stand of all species was estimated about 1910 to contain 1,750,000,000 board feet, running 15,000 per acre, of which more than 40 per cent, or 6,000 per acre, was hemlock, the timber varying in size from 6 to 33 logs to the thousand board feet.

In 1905 and 1906 the Forest Service[2] secured from local timber operators estimates of the amount of standing timber in each county of the Southern Appalachian region. The estimate of standing hemlock was as follows:

	Board feet.		Board feet.
Georgia	205,000,000	Tennessee	1,387,000,000
Kentucky	452,000,000	Virginia	505,000,000
Maryland	60,000,000	West Virginia	3,550,000,000
North Carolina	668,000,000		
South Carolina	93,000,000	Total	6,920,000,000

[1] Report on the Lumber Industry, Part I: Standing Timber. Washington, Government Printing Office, 1913.

[2] Study of Forest Conditions of the Southern Appalachians, under the direction of Walter Mulford.

According to this, hemlock is the most abundant conifer in the mountainous regions south of Pennsylvania. Its nearest competitor is spruce, with a total of less than 3,000,000,000 board feet. In Maryland nearly all the hemlock is in Garrett County. In West Virginia over 80 per cent is in the high mountains of Pocahontas, Randolph, Tucker, and Webster Counties, and the western part of Grant and Pendleton Counties, where it covers large areas just below the spruce belt. Eighty per cent of the hemlock in Virginia lies west of New River, and 50 per cent is in Grayson, Smyth, and Washington Counties. Here, also, the heaviest bodies lie below the spruce in the "spruce and hemlock region." Farther south hemlock forms a smaller proportion of the stand, though it is often very dense in the coves and lower slopes. It becomes less abundant as the mountains become lower, and fails altogether where the foothills and plains begin.

VALUE OF STANDING HEMLOCK.

The stumpage value of hemlock is generally lower than that of the other important eastern trees. White and red pine, white ash, basswood, elm, oak, and hickory all considerably exceed it. Birch and maple, which average a little less in value than hemlock in the northeast, exceed it in the Lake States and Southern Appalachians. Beech is perhaps the only important species in the Lake States whose average stumpage value is not greater than that of hemlock, while in the South hemlock is the least valuable of all the species. Table 6 gives the relative stumpage values of hemlock and associated species in 1912, based on a large number of reports of timber sales received by the Forest Service.

TABLE 6.—*Comparative stumpage values per thousand board feet of hemlock and associated species, in 1912.*[1]

Species.	North-eastern States.	Lake States.	Southern States.
Hemlock	$6.28	$3.78	$2.62
White pine	8.44	10.39	3.91
Ash	9.03	5.82	6.16
Basswood	8.40	6.30	4.92
Elm	6.71	5.87	3.41
Maple	5.98	4.58	3.45
Birch	5.61	4.85	3.33
Beech	4.38	3.67	2.86

[1] From the reports of sales collected by the Forest Service, Office of Industrial Investigations. The States included under the headings of "Northeastern States," "Lake States," and "Southern States" are those given in Table 7.

Stumpage values are derived by deducting all logging, transporting, and manufacturing costs from the value of the lumber or other salable product. Wide ranges in stumpage value due to differences in accessibility may prevail within the bounds of a single State. As

a rule, however, the stumpage value of most of the old-growth timber in a region is uniform enough to justify comparison with other regions. Table 7 gives such a comparison of average stumpage values of hemlock in 1889, 1899, 1907, and 1912, within the States where it is commercially important.

TABLE 7.—*Stumpage values per thousand board feet of hemlock in different States, for 1912,[1] 1907,[1] 1899, and 1889.*

State.	1912		1907		1899	1889
	Average values (sales).	Reports.	Average values (estimates).	Reports.	Average values (estimates).	Average values (estimates).
Northeastern group:						
Maine	$4.72	30	$4.48	33	$2.52	$1.63
New Hampshire	5.57	10	5.22	17	3.19	....
Vermont	5.40	5	4.03	32	2.01	....
Massachusetts	6.44	9	6.10	24	....	....
New York	7.46	29	5.48	33	2.98	....
Pennsylvania	7.35	21	7.38	62	2.75	1.45
Average (weighted)	6.28	....	5.72	....	....	....
Lake States:						
Michigan	5.07	14	4.22	85	2.25	1.05
Wisconsin	3.21	32	3.31	63	2.16	.96
Average (weighted)	3.78	....	3.83	....	....	....
Southern States:						
Maryland	[2] 4.25	[2] 4	3.88	4	....	2.50
Virginia	[2] 3.17	[2] 3	2.98	13	....	....
West Virginia	6.00	1	3.26	45	2.19	....
Kentucky	2.50	2	2.14	9	....	....
Tennessee	2.50	3	2.07	11	....	....
North Carolina	2.17	6	1.43	7	....	....
Average (weighted)	3.05	....	2.84	....	....	....

[1] The figures for 1912 and 1907 are averages of reports collected by the Forest Service. For 1912, reports of both estimates and sales were collected. The averaged estimates (not shown for 1912) were slightly higher for almost every State than the averaged sales.
[2] Estimates.

The table shows that recently the rate of increase in value of hemlock has fallen off, at least in the Northeastern and Lake States. In Pennsylvania, for example, the stumpage value increased more than fivefold between 1889 and 1907, but during the next five years there was practically no increase. In 1889 hemlock was as yet practically unmerchantable in many parts of its range, and its cheapness and low taxable value assured large profits. At present, however, the increase in stumpage value is hardly rapid enough to yield a large profit, while taxes, insurance, and other annual charges often add substantially to the cost. To yield a return of 6 per cent compound interest it would be necessary for the stumpage value to double at least every 10 years. This, of course, applies only to old stands in which growth is very slow or is entirely offset by decay. In young, thirfty stands there is an increase in the amount of stumpage which may make the investment profitable without a great increase in stumpage value.

UTILIZATION OF HEMLOCK.

Though hemlock first came into use because of the growing scarcity and increasing value of better trees, it can no longer be considered merely a substitute for these species. In the three large industries to which it contributes—lumber, pulp, and bark—it has become practically indispensable.

LUMBER.

Small quantities of hemlock lumber were produced locally in the northeast during the early days, but not until the bulk of the pine had gone was it able to find a wider market. As long as the best grades of pine lumber could be had for very little more than the cost of production, hemlock could not be disposed of profitably. As late as 1880 hemlock lumber of the first quality had so little market value in New York and Pennsylvania that it could be shipped only at a loss, and was often sold at the mill to local consumers for as little as $4.50 per thousand board feet. Hemlock logs, cut and peeled for tanbark, could not be hauled with profit even for short distances, and large numbers of them had to be left in the woods to rot. When peeled and well dried, hemlock logs float nearly as well as pine, and because of their slipperiness are useful, when driven with pine and spruce logs in breaking jams. Peeled logs check badly in drying, however, and necessitate heavy and wasteful slabbing. In spite of this drawback hemlock formed an average of about 10 per cent of all lumber on the Penobscot River in Maine from 1851 to 1895, with a steady rise of from 7 per cent in 1851 to 15.3 per cent in 1895.[1]

During the last five years hemlock has ranked fifth in importance among the lumber trees of the United States, being exceeded only by yellow pine, Douglas fir, white pine, and oak. Table 2 shows the annual production of hemlock lumber during recent years, and its proportion in the total annual lumber production.

TABLE 2.—*Hemlock*[2] *lumber production during recent years, from census reports.*

Year.	Annual cut.	Proportion of total lumber cut.	Year.	Annual cut.	Proportion of total lumber cut.
	Thousand board feet.	*Per cent.*		*Thousand board feet.*	*Per cent.*
1899	3,420,673	9.9	1909	3,051,399	6.9
1904	3,268,787	9.6	1910	2,836,129	7.1
1906	3,537,329	9.8	1911	2,555,308	6.9
1907	3,373,016	8.4	1912	2,426,554	6.2
1908	2,530,843	7.6	1913	2,319,982	6.0

[1] From statistics contained in the Third Annual Report of the Forest Commission of the State of Maine, 1896, Appendix, p. 7.

[2] Including western hemlock, an entirely distinct timber tree, which increased from 0.02 per cent of all hemlock cut in 1899 to over 12 per cent in 1913.

As the higher grades of pine grew scarce and expensive, hemlock acquired a modest value of its own as a competitor with the successively lower grades of pine which were being introduced. Only the best hemlock was at first put on the market, but afterward lower grades came in for box manufacture and other purposes for which high-grade lumber was not required.

The production of only the best grade of hemlock necessarily involved a great deal of waste both in logging and sawing. Partially defective logs were culled out in the woods, because the lumber they contained would not pay for their removal. Hemlock, when mature, is commonly wind shaken and rotten at the butt, and branchy and tapering at the top, so the amount thus left was naturally very large. Many trees which contained some sound lumber were left standing. In the mill, peeled logs had to be heavily slabbed to remove season checks, and much of the heartwood might be unsalable because of knots and shakes. Many of the slabs and edgings were made into laths, but far more were burned. As lower grades of lumber became salable there was less waste; trees were cut farther into the top and shorter butts were taken, while slabs and edgings were sold to pulp mills. In some parts of the country the broken logs and tops left after logging are now cut into bolts and used for pulp. Means of utilizing waste are rapidly increasing, and the present problem is, which of these will pay best?

Though inferior to yellow pine and Douglas fir where great strength is required, hemlock lumber makes good building material and is said to give greater strength and firmness than white pine. It is well adapted for frames, sheathing, roofing, floor lining, and other construction purposes. It is softer and lighter than southern pine or Douglas fir, but holds nails as well. As drop siding it makes an excellent outside finish for barns and houses, if kept well painted. The best grades make attractive inside finish wherever a soft wood is appropriate.

The durability of the wood depends very largely upon the nature of its use. In contact with the soil it is very perishable, and is not well adapted for ground sills unless treated with a preservative. If kept in a dry place, however, it is extremely durable. Even as outside covering it will give good service if placed so that it dries out rapidly and thoroughly after being wet. There are instances of hemlock barns which still stand after 50 or more years' use. Shaved hemlock shingles, if of good, straight-grained wood and used on a moderately steep roof, are practically as durable as white pine shingles. An important defect of hemlock for such uses is its liability to check and split when exposed to the sun. Hemlock laths are said to make a firmer and better wall than pine, though harder to nail than either the latter or basswood.

Table 3 gives the average mill-run value per thousand board feet of hemlock lumber in different States for years for which census figures are available.

TABLE 3.—*Average value per thousand board feet of hemlock lumber, by years and States.*

State.	Value of lumber per 1,000 board feet.								
	1912	1911	1910	1909	1908	1907	1906	1904	1899
Northeastern group:									
Maine	$14.53	$14.64	$15.87	$14.03	$13.75	$15.37	$14.76	$11.66	$10.83
New Hampshire	15.08	14.89	14.99	15.02	13.98	15.49	14.85	11.72	10.70
Vermont	15.59	14.65	14.96	14.38	14.95	16.04	16.51	12.54	10.19
Massachusetts	....	16.51	16.59	15.59	13.39	15.84	14.88	13.28	11.84
New York	15.98	15.50	16.68	16.70	15.00	20.00	19.00	13.96	11.10
Pennsylvania	15.41	15.54	17.08	17.56	16.29	16.42	17.16	12.65	10.46
Lake group:									
Michigan	13.19	12.44	12.51	11.86	12.02	14.79	13.40	11.22	9.00
Wisconsin	13.00	13.03	12.25	12.06	12.34	14.60	14.43	11.07	9.37
Southern group:									
Maryland	....	14.33	14.94	12.97	14.53	16.63	15.69	12.98	7.98
Virginia	....	13.75	11.25	13.02	12.71	13.86	14.49	13.51	9.95
West Virginia	14.64	14.66	14.69	14.81	13.68	15.56	16.12	11.52	8.29
Kentucky	....	12.36	12.27	13.31	13.02	14.65	12.64	11.23	9.05
Tennessee	....	11.89	10.57	13.64	11.76	13.72	13.99	11.85	8.97
North Carolina	....	11.08	9.73	11.61	12.07	12.29	13.14	9.51	9.87
Average	....	13.59	13.85	13.95	13.65	15.53	15.31	11.91	9.98

From table 3 it will be seen that the value of hemlock lumber has fluctuated from year to year, both locally and for the country as a whole. The price was highest in 1907, and the effect of this upon stumpage values during the subsequent years is shown elsewhere in this bulletin. There are, of course, local deviations from the average values given for a State. In central Wisconsin, for example, an average price of about $15.40 per thousand board feet, mill run, prevailed in December, 1912. Apportioned by grades this amounted to $17.50 per thousand for No. 1, $15.50 for No. 2, and $10.50 for No. 3 lumber. During 1911 average prices of $15.40, $12.65, and $7.44 per thousand, respectively, were received for the same grades by one large firm in the same region. Compared with these values the prices paid for hemlock logs are high. Prices paid by operators at Wausau, Wis., are about as follows:

Length of logs.	Winter of—		
	1912–13	1911–12	1910–11
Feet.			
12 to 14	$9.50	$7.50	$8.00
16 to 16	10.00	8.00	8.50
18 to 20	10.50	8.50	9.00
22 to 24	11.00	9.00	9.50

The logs were scaled by the Scribner "Decimal C." rule.

PULP.

In 1905 hemlock formed 11.8 per cent of all the wood used for pulp. In 1906 and 1907 it supplied 14 per cent of the total amount; in 1908, 17 per cent; in 1909, 14 per cent; and in 1910, 15 per cent. During the latter year its consumption was 50 per cent greater than in 1905.

Hemlock pulp is used for news, wrapping, and other cheap grades of paper, and is manufactured chiefly by the sulphite process. In this process the wood is first chipped and then cooked in a solution of calcium sulphite, which frees the fibers by dissolving the substances that unite them. The dissolved substances comprise about half the original weight of the dry wood, without bark. Hemlock also furnishes a small amount of ground wood pulp, but the great bulk of this is spruce. Ground wood is inferior to chemical pulp, since the fibers become broken in grinding, while the pulp contains the useless constituents which are dissolved out in the chemical process. As a result it is mealy and less interlaceable, especially in the case of hemlock, the fibers of which are shorter than those of spruce. In spite of this, a very serviceable grade of news paper can be made from hemlock pulp, 75 per cent ground and 25 per cent sulphite, with almost the strength, finish, and appearance of that made chiefly of spruce.[1]

Since the value per ton of ground wood is only about $15, as compared with $47 for sulphite pulp, the former is used as the basis for news and other cheap grades of paper, to which a small amount [2] of sulphite pulp is added for strength. Spruce once furnished practically all of both kinds of pulp, and still supplies 90 per cent of the mechanical pulp. Its increasing cost has brought about the use of cheaper woods in the sulphite process, during which so much of the volume is lost. Spruce now supplies less than 60 per cent of the sulphite pulp, while hemlock supplies about 25 per cent. The proportions of hemlock manufactured by the various processes for the six years from 1905 to 1910, inclusive, were—

	Per cent.
Sulphite process	94.75
Mechanical process	4.5
Soda process	.7
Sulphate process	.05
	100.00

Hemlock pulpwood is marketed both as cordwood and in the log. In Wisconsin pieces 8 inches and over at the small end are ordinarily cut in log lengths and sold by the thousand board feet, 1,000 board feet usually being considered equivalent to 2 cords. Pieces

[1] J. H. Thickens: "Experiments with Jack Pine and Hemlock for Mechanical Pulp." Dept. of Agriculture, Forest Service Forest Products Laboratory Series, June 11, 1912.

[2] The usual proportion is from 70 to 84 per cent ground pulp to from 16 to 30 per cent sulphite.

less than 8 inches at the small end are sold by the "gross cord," or cord containing 128 cubic feet of stacked (not solid) wood, with the bark on. Unlike most cordwood, however, the pieces are not cut in 4-foot lengths, but usually in lengths of 8 feet, 12 feet, etc., according to the demands of the mill to which they are sold. Pieces less than 4 inches at the small end are rarely accepted. About 65 per cent of the wood is sold with the bark on, 33 per cent peeled, and about 2 per cent rossed.

The use for pulp of waste material left after lumbering has recently been introduced in parts of Pennsylvania (see Pl. II, fig. 2). Hemlock tops and broken and defective logs are peeled, cut into 5-foot lengths, piled in the woods, and sold by the cord. The success of this practice disposes of the contention that the knots in hemlock tops make their use for pulp impracticable. From 250,000 to 260,000 cords of slab wood and other sawmill waste are now consumed every year for pulp. About 85 per cent of this is manufactured as sulphite pulp, and practically all the rest as ground wood. In 1908 hemlock formed 41 per cent of the sawmill waste used, and its average value was $4.07 per cord—about two-thirds that of hemlock cordwood in the round. In Wisconsin, sawmills often sell their hemlock slabs to the paper mills for $3 per cord, dry, or $2 green.

The cost and value per cord and per thousand board feet of pulpwood vary somewhat in different regions, and there are constant fluctuations due to changing business conditions. The price also depends upon whether the wood is sold peeled, rossed, or with the bark on. In 1909, according to census reports, wood with the bark on sold for $5.98 a cord, while peeled wood brought $6.58, and the small amount of rossed wood $12.31 a cord.

The average f. o. b. value per cord of hemlock in different regions in comparison with other pulpwoods is shown in Table 4.

TABLE 4.—*Average f. o. b. value per cord of hemlock pulpwood compared with other species.*

[Compiled from census reports for 1907, 1908, and 1909.]

Region.	Year.	Hemlock.	Spruce (domestic).	Balsam.	Poplar (domestic).
Total	1907	$5.68	$8.55	$7.59	$7.85
	1908	6.02	8.76	7.23	8.01
	1909	6.30	9.32	8.28	7.96
New England	1907	7.10	8.48	8.30	7.51
	1908	7.18	8.51	7.58	7.54
New York	1907	6.79	8.13	9.17	8.25
	1908	7.47	8.58	8.22	8.49
Pennsylvania	1907	5.13	9.26	....	8.62
	1908	5.05	10.94	9.53	9.16
Lake States	1907	5.83	9.88	5.84	4.45
	1908	[1] 6.36	10.05	6.39	4.93

[1] During the financial depression of 1908 the market value of hemlock logs in northern Wisconsin dropped in some cases to $7 per thousand board feet (equivalent to $3.50 per cord) f. o. b. cars. No logger would deliver hemlock pulpwood for less, and of this amount, $2.50 would probably go to the jobber to whom the work was let out.

Pulp mills may pay as high as $12 per thousand board feet, in the log, and accept crooked logs. This fact is important in view of the low "mill run" value of hemlock lumber, which is rarely much over $15 per thousand board feet at the mill, and for which crookedness is a more or less serious defect. The pulp mills also prefer to receive their wood peeled, and will often pay $1 more per thousand board feet for peeled than for unpeeled logs. Peeled logs are cheaper to transport and more durable than unpeeled ones, and there is no expense for rossing. On the other hand, stripping tanbark from saw logs often greatly reduces their value, due to the serious checking which results. Bark peeling can be done more profitably when logs are cut for pulp than for lumber.

The value of hemlock cordwood in Wisconsin is about $3.50 per cord when logs are selling at $8.50 per thousand board feet, and about $4 per cord when logs sell at from $9 to $12 per thousand. The cost of getting out cordwood is about $2.50 or $3 a cord. Until quite recently hemlock pulpwood stumpage at many places in Wisconsin has been valued at 50 cents a cord.

TANNING.

Hemlock bark has been used in tanning practically ever since the beginning of the industry in America. Oak bark is preferred, since it makes the leather softer, more pliable, and less permeable to water than does hemlock; but there is not as much of it, and for many years its annual consumption in tanning has been less than half that of hemlock. With the introduction of tanning extracts, hemlock and oak were the first native species to be used, but after the process by which extract could be made from chestnut wood was perfected, about 1900, the latter species became the leading source of supply. In 1909 it supplied practically half the extract used, while the amount supplied by hemlock had fallen to about 3 per cent of the total quantity. The amount of hemlock bark made into extract was never a large part of the total hemlock bark consumed in tanning; in 1900 it formed about 1 per cent, in 1907 and 1908 slightly exceeded 8 per cent, and in 1909 had fallen to less than 3 per cent.

Table 5 gives the total annual consumption of tan bark and extract in the United States, with the proportion supplied by each of the leading native species, and the value per cord of hemlock and oak bark. The figures are from census reports for different years. For convenience, the percentage figures, when they include decimals, are expressed as the nearest whole number.

A MATURE HEMLOCK TREE.

The clean, columnlike bole indicates an advanced age. North Carolina.

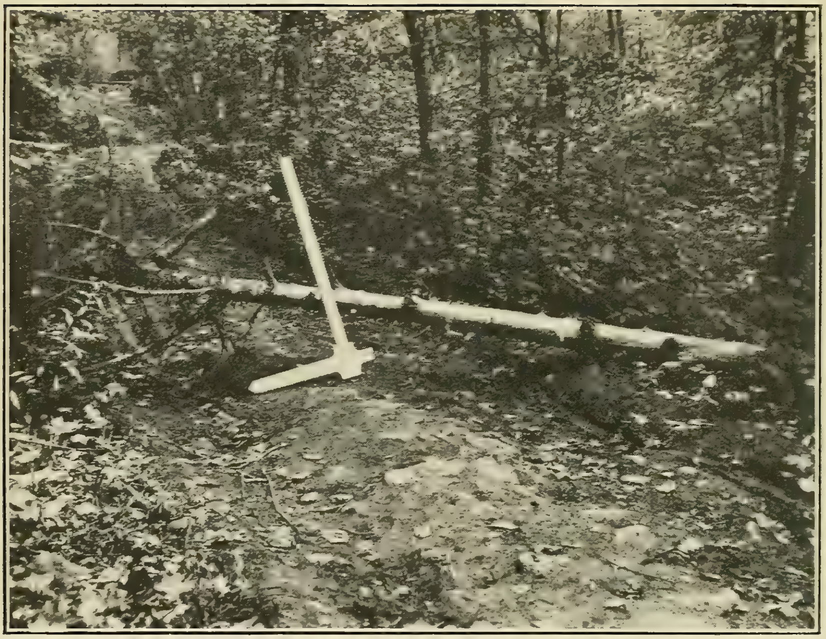

FIG. 1.—BARK PEELING TO A DIAMETER OF LESS THAN 4 INCHES IN THE TOP.

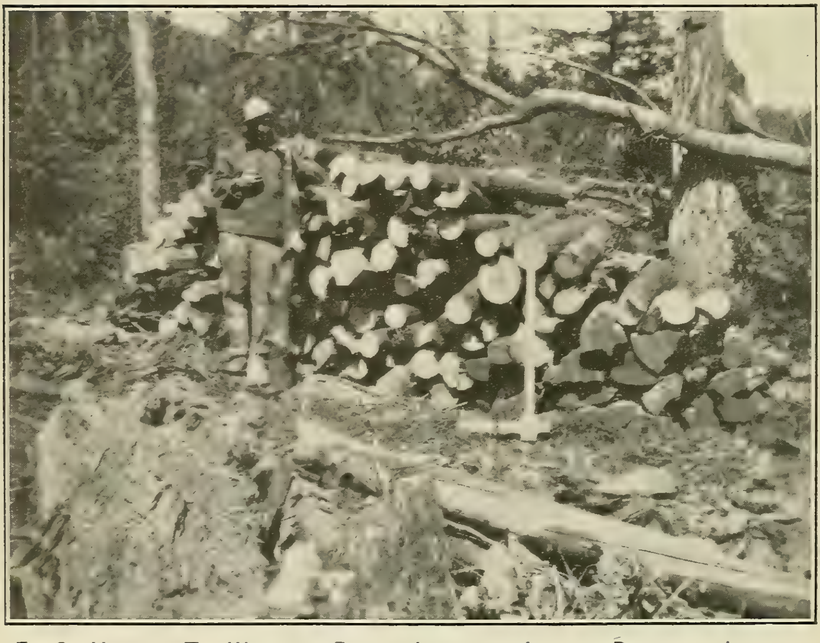

FIG. 2.—HEMLOCK TOP WOOD AND BROKEN LOGS ONCE LEFT TO ROT AFTER LOGGING NOW BRING A GOOD PRICE AS PULPWOOD.

CLOSE UTILIZATION OF HEMLOCK IN PENNSYLVANIA.

TABLE 5.—*Consumption of tanning materials: 1900, 1905–1909.*

[Compiled from census reports for these years.]

Year.	Consumption of bark.		Proportion of total.		Average price per cord.	
	Total.	Hemlock.	Hemlock.	Oak.	Hemlock.	Oak.
	Cords.	*Cords.*	*Per cent.*	*Per cent.*		
1900	1,616,065	1,170,131	72	28	$6.28	$7.12
1905	1,104,045	799,755	73	27	6.32	10.44
1906	1,371,342	931,152	68	30	8.49	10.87
1907	1,214,401	815,840	67	31	8.60	10.51
1908	1,127,400	810,231	72	27	8.89	10.80
1909	1,078,910	698,365	65	30	9.21	10.90

Year.	Consumption of Extract.		Proportion of total.			Average price per barrel.		
	Total.	Hemlock.	Hemlock.	Oak.	Chestnut.	Hemlock.	Oak.	Chestnut.
	Barrels.	*Barrels.*	*Per ct.*	*Per ct.*	*Per ct.*			
1900	67,043	12,812	19	81	....	$11.78	$10.14	....
1905	292,399	52,430	18	64	17	....	....	....
1906	658,777	68,811	10	9	39	12.31	9.91	$9.13
1907	729,599	80,267	11	8	38	12.06	10.38	9.51
1908	784,202	81,617	10	6	37	12.78	10.60	9.72
1909	773,635	21,725	3	10	48	12.72	9.52	9.80

This table shows that there has been a gradual but steady decline in the quantity and an increase in the value per cord of hemlock bark used directly by the tanneries. By far the largest part of the hemlock bark and extract used is produced in the States of Pennsylvania, Wisconsin, Michigan, New York, and West Virginia, ranking in importance in the order named.

Sales of hemlock bark, though nominally by the cord, are actually by the ton, and in most cases the cord must weigh 2,240 pounds. The bark is peeled in the spring and piled in the woods. The peelers are paid by the bulk cord—8 by 4 by 4 feet. Trees as small as 8 inches in diameter breast-high are sometimes peeled, but the bark of small trees is thin and light, and rolls up when dry, so that a cord (by weight) may be a pile 12 feet instead of 8 feet long. Wisconsin bark is thinner and lighter than bark from Michigan, and tanners will not pay as much for it. Lumbermen commonly assume that a half cord of bark can be obtained for each 1,000 board feet of lumber. This is about right for trees 20 inches in diameter. Smaller trees yield more bark per 1,000 board feet and larger trees less. Economy in bark peeling is rapidly increasing, and trees are now peeled to much smaller diameters in the top than formerly (Pl. II, fig. 1).

The volume of bark obtainable from trees of different sizes is shown in Tables 18, 19, and 20, Appendix.

MINOR USES.

SHINGLES.

Because of the prevalence of shake, hemlock is not well adapted for shingles, unless these are carefully sawed and well graded. It ranks seventh or eighth among the species most used. Census figures show a steady decrease in the manufacture of hemlock shingles from 1899, when nearly 392 million were made, until 1911, when only about 26 million were produced. These figures correspond to 3.2 per cent and 0.2 per cent, respectively, of the total annual production of shingles.

CROSSTIES.

About 2.5 per cent of all crossties used in the United States are of hemlock, which ranks about ninth among the tie-producing species. Between 1906 and 1911 the annual production of hemlock ties increased from 2,058,000 to 3,686,000. Nearly all of these are hewed ties and are used by steam railroads. Oak and cedar are more durable, but hemlock compares favorably with the other woods used, and is said to hold spikes better than the cedar without tie plates. The average cost of hemlock ties is from 28 to 38 cents, which is, in general, lower than for other species.

Untreated hemlock ties have been estimated[1] to last about 5 years, which is also the estimated life of untreated beech, birch, and maple ties. The estimated duration of cedar ties is 11 years; of white oak, 8; of chestnut, 7½; of tamarack and spruce, 7; and of black oak, 4 years. Preservative treatment is said to triple the life of hemlock ties. In 1911, 535,255 hemlock ties—14.5 per cent of all produced—were treated with preservative, nearly all—98.5 per cent—with a mixture of zinc chloride and creosote; the remainder with creosote alone.

SLACK COOPERAGE.

Slack cooperage is primarily a hardwood industry, and aside from pine, which leads in the production of heading and is second in that of staves, the conifers are but poorly represented. Hemlock has never supplied much material for this industry, and its importance is rapidly diminishing. In 1909, which is the last year for which hemlock is listed separately in census statistics, it ranked sixteenth among the species supplying the industry, and contributed less than 1 per cent of either staves or headings. The annual production of hemlock staves is from 10 to 12 millions, and of headings, about 1,200,000 sets.

VENEER.

A very small amount of hemlock—less than 1 per cent—is used annually for veneer manufacture. In 1909, hemlock ranked twenty-

[1] "Wood Preservation," by W. F. Sherfesee and H. F. Weiss, in Report of National Conservation Commission, 60th Cong., 2d sess., S. Doc. 676, 1909, p. 663.

fourth among veneer-producing species, with an annual consumption of 207,000 board feet of logs. Most of the hemlock veneer is made in New York, while Maine, Pennsylvania, Ohio, North Carolina, and the Lake States contribute small amounts. It is employed chiefly in the manufacture of shipping packages of various kinds, laminated or built-up lumber, etc.

Because of heart defect (knots, shake, and decay) hemlock cores left after veneer production are of little value for anything but fuel.

STRUCTURE AND DEVELOPMENT OF THE TREE.

During youth, hemlock is the most graceful and beautiful of eastern conifers. Though young trees in dense shade are usually flattened and unsymmetrical, saplings which receive enough light will develop a straight, slender, tapering stem, and a sharply conical, symmetrical crown. The terminal shoots and branch tips lack the rigidity common to pine, spruce, and fir, and the crown is formed of slender, horizontal branches with graceful sprays of branchlets and twigs. The branches are rather uniformly distributed over the stem, though not in regular whorls, as in white pine. The "leader," or terminal shoot, droops in a direction away from the prevailing wind.

Full-grown hemlocks have very straight, symmetrical, undivided trunks. The taper is greater than that of white or red pine, or, in fact, of most of its common associates, and is due to the remarkable persistence of live branches along the stem. The crown is very long and dense and of a conical shape. In mature trees it commonly covers the upper two-thirds of the stem, and may be 60 or 70 feet long by 30 or 40 in total spread. It is formed of slender, horizontal, or somewhat drooping limbs, which clothe the tree densely and evenly on all sides. When the growth is vigorous and the side shade very dense, the limbs of mature trees are killed to a height of 50 or even 60 feet above the ground, but the dead limbs are retained tenaciously, so that even under these conditions an actual clear length of 30 feet is uncommon except in very old trees (Pl. I). The mature trunks usually bear numerous small, sound, dead stubs almost to the ground, and good-sized limbs at 20 or 25 feet from the ground.

When full grown, hemlock varies in total height from about 100 feet, in good soil in the western part of its range, to over 160 feet in mountainous portions of West Virginia, North Carolina, and Tennessee. Diameters at breastheight of 3 or 4 feet are now exceptional, though trees 5 and even 6 feet in diameter have been measured. One tree cut near Hermon, N. Y., measured 115 feet in height, 5 feet in diameter, and contained 5,562 board feet.[1] Trees yielding 10,000

[1] From the "Paper World," Jan. 4, 1902.

board feet each are reported to have been cut in Tucker County, W. Va. Such dimensions sometimes are found to correspond to an age of 500 or 600 years.

The average contents in cubic feet and board feet of hemlock trees of different heights and diameters are given in Tables 12 to 17, Appendix. In addition, Tables 21 and 22, Appendix, show the diameters, inside bark, at different heights from the ground corresponding to the small ends of 8 and 16 foot logs.

THE WOOD.

Hemlock wood is soft, light, stiff, but brittle, not strong, splintery, and commonly cross-grained. Its worst defect, aside from a tendency to decay, is "shake," which is the tearing apart of the wood between annual rings caused by the tree bending in the wind. This condition is very common, especially in old trees. "Shaky" lumber splits so easily as to be worthless for many purposes.

In color the wood is light buff with a red-brown tinge. In structure it differs from pine and spruce wood in the more abrupt transition between the hard, dark summerwood and the soft, light, springwood, a contrast which gives the lumber a handsome figure. The fuel value of hemlock is low, though slightly higher than that of white pine. The per cent of ash is 0.46. Sargent[1] computes the specific gravity of absolutely dry hemlock wood at 0.4239, a cubic foot weighing 26.42 pounds. The shipping weight per thousand board feet of ordinary seasoned rough lumber varies from 2,400 pounds for 1-inch board to 3,500 pounds for heavy timbers.

BOTANICAL CHARACTERISTICS.

BARK.

The bark of merchantable trees in the Lake States comprises about 19 per cent of the total cubic volume, and this proportion varies but little with the size of the tree. In the Southern Appalachians the proportion varies from 15 per cent for 6-inch trees to 19 per cent for trees 26 inches and over. When 15 or 20 years old the bark begins to break up into thin, partly loosened flakes, or scales, and still later becomes traversed by deep, longitudinal fissures. In old trees the bark is often 2 or 3 inches thick at the stump, gradually decreasing with height to a thickness of from 0.3 to 0.5 of an inch at the point where the tree is 6 inches in diameter. It consists of two distinct layers, the inner relatively very thin, white, and fibrous, the outer thick, deep red, and brittle.

ROOTS.

Seedlings form a slender taproot during the first year, which is later lost in the development of lateral branches. These are numerous,

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[1] C. S. Sargent, "Silva of North America," vol. 12, p. 65, 1898.

and the older ones become very large. The latter are covered with a thick firm bark, the outer and thicker layer of a pale red color, the very thin inner layer white. On the whole, hemlock is a shallow-rooted species, and can thrive on very shallow soil. In deep soils, however, the roots often penetrate to some depth.

LEAVES.[1]

The leaves are small, flat, and narrow, and differ from those of other northeastern conifers, except Carolina hemlock and the Canadian yew or ground hemlock, in that their bases are contracted into a very short stalk or petiole. (See *c*, fig. 2). They are usually from one-third to two-thirds of an inch long and about one-fifth as wide. Their color when they first appear is a fresh, light green, which soon changes to a dark, lustrous green on the upper and whitish green on the under surface, where the stomata are located. The leaves fall during their third season.

BUD SCALES.

The few exterior scales of both flower and leaf buds are thick and dark brown in color, while the inner scales are numerous, whitish-green, becoming brown with age, thin, but of an exceedingly firm structure. The scales remain persistent after the buds have expanded, those of the leaf buds not wholly disappearing until the fifth or sixth year. Up to this age the persistence of the scales affords a ready means of determining the age of a branch.

FLOWERS.

In the latitude of central New York the flowers expand about the first of June. The male flowers appear in the axils of leaves on shoots of the previous year, or less frequently on twigs which are two or sometimes three years old (fig. 2). The female flowers are borne singly at the ends of the twigs.

CONES.

The female flower, after fertilization, grows rapidly, and by October becomes the ripened fruit—the cone. (See *d*, fig. 3.) Cones are from one-half to three-fourths of an inch long and of equal breadth when dry and the scales expanded, but only half as broad when closed. They are pale green in color until maturity, when they become dark brown. Only about 20 of the scales in the center of the cone are seed bearing, the others being small and rudimentary. In a mature cone, when dry, the scales are widely separated from each other, standing at an angle of about 45 degrees with the axis, but when wet they become appressed and closely overlap each other.

[1] The description of the following parts of the tree are drawn largely from a manuscript report on the general structure and anatomy of hemlock by Prof. Atbey N. Prentiss, of Cornell University.

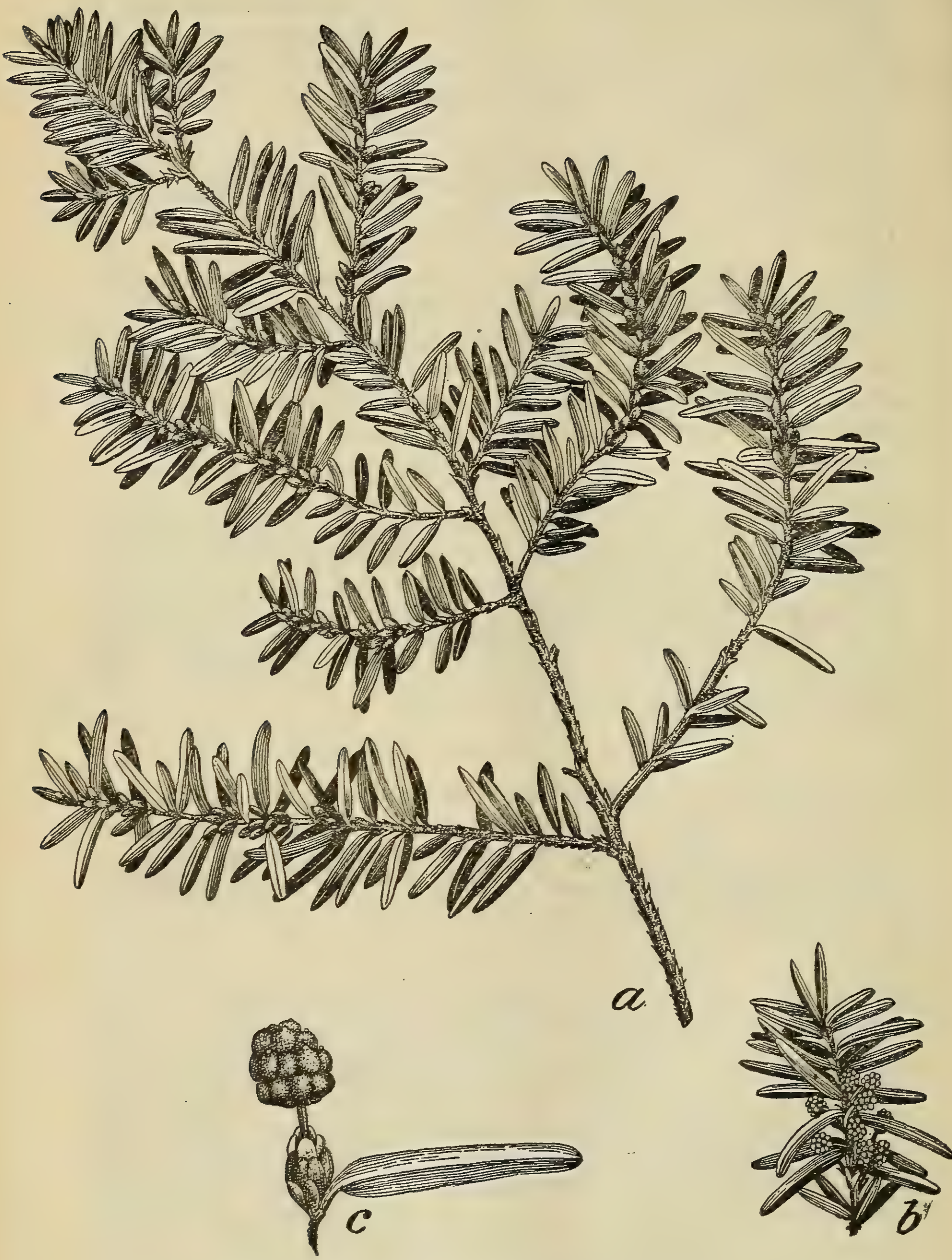


FIG. 2.—*Tsuga canadensis.* *a*, Branchlet showing staminate flowers in early spring; *b*, staminate flowers fully developed; *c*, detached staminate flower, enlarged.

The cones are extremely sensitive to moisture, a small amount of water causing the scales to close rapidly. When thoroughly wet the scales of a cone become completely closed, in some cases within 10 minutes and in most cases within 20 minutes. Even a damp atmosphere, without the actual contact of water, will cause the cones to close to some extent.

The advantage to the species of this property of the cone is apparent. The cones when mature expand their scales so as to permit the seeds to escape, but as the latter are attached to a membranous wing which adheres to or rather forms a part of the inner face of the scale, they do not easily fall out. A passing shower or a rain causes the scales to close, again to open as the air becomes dry. This process continues for many months, with the effect of loosening the seeds successively from autumn until spring, and thus a bearing tree makes a succession of sowings extending over a considerable length of time. As a result the wind, blowing during this period from different points, carries the seed now in this direction and now in that, and thus a fruiting tree stands in the center of a considerable area which it has sowed with seed.

SEED.

The seed (see *f* and *g*, fig. 3) is about one-sixteenth of an inch long and about two-thirds as broad. The attached wing, an exceedingly delicate and almost transparent membrane, extends about a fourth of an inch beyond the end of the seed, and is an eighth of an inch broad at its widest point. On the under side, next to the cone scale, are a number of minute glands or vesicles, usually from 4 to 8, each containing a minute drop of oil. The seed of the Carolina hemlock has 15 or 20 vesicles, which are much smaller in size than those of the common species.

According to Forest Service determinations, there are about 400,000 clean seed (without wings) per pound. The seeds weigh 1.13 grams (0.04 ounce) per 1,000, and the germination per cent is from 30 to 60.

MANNER OF GROWTH.

In the climate of central New York the growth of a vigorous tree usually begins during the first half of May. The terminal buds are the first to open, and in about two weeks develop into shoots a half inch long, thickly set with the half-grown, yellowish-green leaves. The dark-green twigs and branches appear as though fringed with gold; and it is now that the hemlock tree takes on its most striking and peculiar beauty. The shoot continues its growth during the season, being constantly tipped with a rosette of small, forming leaves, while those previously formed are scattered on the constantly growing stem.

FIG. 3.—*Tsuga canadensis*. *a*, Seedling a few days old; *b*, seedling, one month old; *c*, seedling, one year old; *d*, mature foliage and ripe cones; *e*, lower side of detached cone scale; *f*, upper side of cone scale with its seeds and views of latter detached; *g*, lower side of seed showing resin glands (twice natural size).

The stem does not grow throughout its whole length, but at a certain point it becomes mature, and growth ceases. During the season this point lies something more than an inch back from the tip, and is constantly moving forward as the stem grows, until at the close of the season it coincides with the end of the stem.

While the shoot of the season is growing in length, it is also at the same time developing lateral growths or branches. (See *a*, fig. 2.) These lateral growths begin to appear about the middle of June, in the form of minute rosettes of leaves similar to that at the end of the main shoot, and grow in a manner similar to the main stem, only far more slowly. In vigorous plants the main shoots often reach a length of 8 to 12 inches, while the strongest of the lateral shoots scarcely reach an inch in length.

Winter buds begin to form about the middle of September at the end of the main shoot and of its branches, and also in the axils of many leaves of the main shoot.

The tree reaches its fruiting stage usually when from 20 to 40 years old and from 15 to 25 feet in height. The staminate flower buds begin to develop about the 1st of July and by the last of the month have become well formed. In general appearance they resemble the lateral leaf buds, but are twice the size and more conical in form. Sometimes every leaf, or at least a portion of a flower-bearing shoot, has a flower bud in its axil.

The pistillate flower buds also begin to develop early in July, but grow more slowly than the staminate buds. When fully formed they are about the same size as the latter, but their exterior scales are of a much firmer texture and deeper brown in color, while their bases are covered with the overlapping scale processes of the neighboring leaves. Though both kinds of flower buds occur on the same general branch, they are both rarely borne on the same shoot. In other words, while the plant as a whole is monœcious, the shoots of the season are diœcious.

A wide difference exists in the vigor and size of flower-bearing and leaf-bearing shoots. On young and thrifty trees the latter are often 8 to 10 inches in length, while on trees of fruiting age they rarely exceed an inch or an inch and a half in length.

ASSOCIATED SPECIES.

In one part or another of its range hemlock grows in mixture with a number of tree species. There are, however, four kinds of forest in which it is a characteristic and important element; hemlock in mixture with either yellow birch, beech, or sugar maple, or with all three; hemlock with white pine; hemlock with red spruce; and hemlock in practically pure stands. Other species than those just men-

tioned are always scattered through these forests, and an extra abundance of one or more of them in mixture with hemlock may give rise to distinct local forest types. Among such species are white spruce, balsam fir, white and rock elms, basswood, paper birch, sweet birch, red maple, and black cherry. In the South, yellow poplar, shagbark and shellbark hickories, white, red, and post oaks, and cucumber often grow with hemlock in the coves, while black, scarlet, and chestnut oaks, pignut and mocker nut hickories, and chestnut are its usual associates on slopes and ridges.

EFFECT OF LIGHT, SOIL, AND MOISTURE ON THE COMPOSITION OF THE STAND.

The heavy foliage of hemlock adds greatly to the density of any stand in which the tree grows. Since it will endure a heavier shade than any of its associates, hemlock finds little difficulty in establishing itself under them, even when their crowns form a fairly dense cover. For this reason the forests of which it forms a principal part nearly always contain trees varying widely in age and size. This is especially true when it grows in mixture with species like beech, sugar maple, spruce, and balsam, which are also shade-enduring. Trees like white pine, which require more light than hemlock, can succeed in mixture with it only by growing more rapidly and to a larger size, thus keeping their crowns above or at least as high as those of the hemlocks. In mixed stands of white pine and hemlock there is usually a dense understory of the latter species, which is the only one able to establish itself in the shade of the crowns. In this way hemlock is able to creep into stands of pine and other species, and by its superior shade endurance gradually assume predominance. (Pl. III.)

Under the particularly dense shade of hemlock and spruce stands, and in thickets of rhododendron and other heavy-foliaged undergrowth, hemlock seedlings find it exceedingly difficult to survive, and the few which do survive grow with extreme slowness as long as the shade remains heavy. (Pls. IV and V.) When, however, light is admitted not too abruptly they rapidly recover from suppression.

Hemlock is essentially a tree of fresh or moist soils; in other respects its soil requirements are not exacting. In mixture with hardwoods it usually grows on loamy soils, ranging from sand loam to clay loam, rich in decayed vegetable material; and with white pine on sandy soils, well mixed with humus. Hemlock will grow on limestone soils, if not too dry, as well as on moist, almost swampy, loamy clays. Like all its common associates, it does best on deep, fertile, moist, but well-drained soils, where it and the hardwoods tend to crowd out the more light-needing white pine.

The shallow roots of hemlock are extremely sensitive to drying out of the surface soil, which in part accounts for the death of trees exposed to increased light, as when a road is cut through the woods, or near-by trees are removed in lumbering.

In mountainous regions hemlock usually occupies the cool, moist, northerly and easterly slopes, coves, benches, and sides of ravines, often reaching the edges of streams, but avoiding extremely wet and swampy places. On north and east slopes of ridges it often ascends to the crest, and may grow along the edges of rocky cliffs and bluffs. In New Hampshire it ranges from near sea level to about 2,400 feet, but in Georgia and Alabama it is not found below an elevation of about 800 feet, and reaches this level only in cool and humid situations.

REPRODUCTION.

Hemlock is a prolific seed bearer, but reproduces poorly. Trees receiving a moderate amount of light begin to bear seed when from 30 to 50 years old. As a rule seed is produced abundantly every two or three years, but ordinarily only from 30 to 60 per cent of the seeds are fertile. The cones mature in a single season, and the seeds fall from them during the late autumn and winter, germinating in the spring, from March to the end of May. On account of their small size and their large, membranous wings, the seeds may be borne considerable distances by the wind. They will germinate and take root in poorly drained situations, on moss-covered logs and decayed stumps as well as in fresh, mineral soil; but the best seed bed is a moist, well-decomposed leaf litter in which the seeds become completely buried.

Too much or too little shade will kill hemlock seedlings. For this reason reproduction is rarely found either under the heaviest shade of the parent trees or in clearings and burned-over areas, but is usually abundant in the more open portions of the hemlock forest or under the lighter shade of hardwoods or pine in mixture. If the water in the soil is not stagnant, more seedlings will survive in very moist than in relatively dry situations. The seedlings grow best when in deep, moist layers of mellow decaying leaves and twigs overlying fresh but well-drained loamy soils. The decay of the leaves and twigs breaks down their chemical structure and releases various food materials for the seedling hemlock. These materials become available largely or only through the agency of certain fungi, called mycorrhiza, which exist as felted layers of fine, thread-like mycelium, completely inclosing and even penetrating the rootlets. Many of the threads extend out into the mass of decaying humus, and through these the products of decay are conducted from the decomposing leaves to the felt, and thence into the rootlets, where they become serviceable for nutrition and growth. It is

probable that the best conditions for the development of hemlock mycorrhiza exist where the soil is sweet or only slightly acid and where a good crown cover is maintained.[1]

Hemlock reproduction is rarely found in clearings, a condition for which fire is chiefly responsible, though other causes, such as intense sunlight and evaporation, no doubt play a part. Fire, however, while actually promoting the reproduction of many species by exposing the mineral soil, may at the same time entirely prevent that of hemlock by destroying the organic constituents of the forest soil. In the relatively few hemlock regions from which fires have been kept out after logging remarkably thrifty stands of second growth have often developed. Such second-growth hemlock in the Tionesta Valley and elsewhere in the northern Alleghenies is undoubtedly due to the absence of fires in these localities in the past, while the entire absence of hemlock in other localities as favorable to its growth can be attributed to the burning of seedlings and soil.

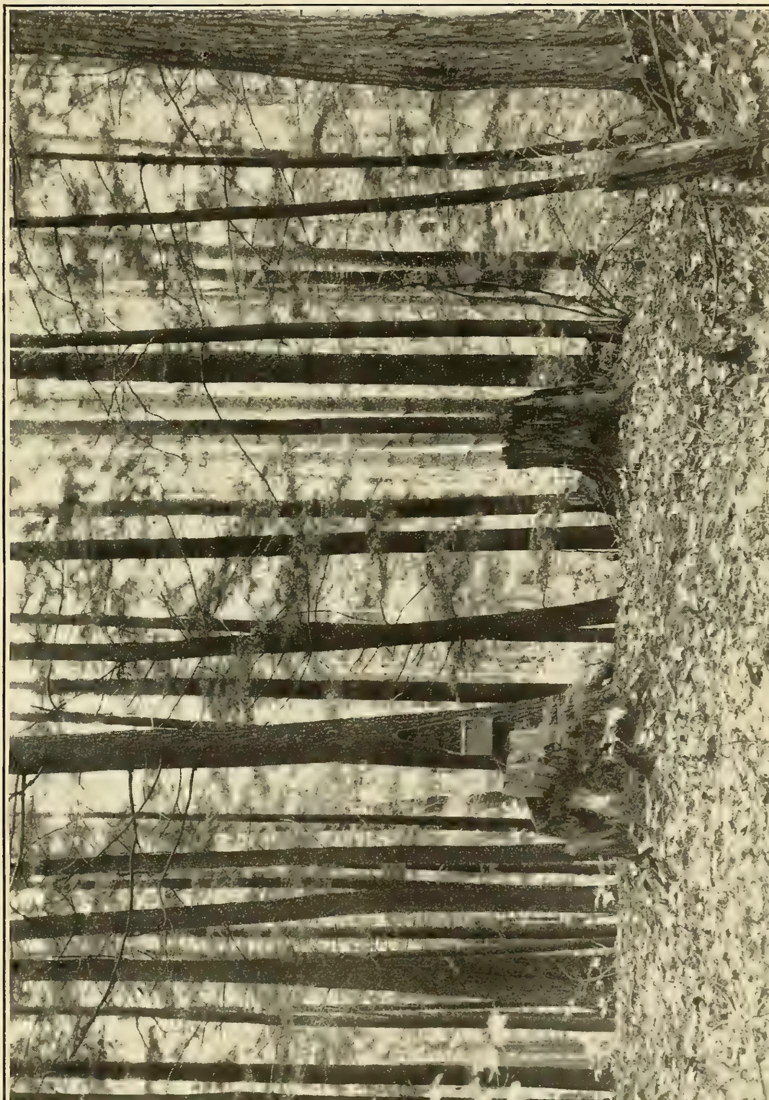
Even-aged stands of hemlock second growth are very rare. Small groups occur in protected valley bottoms and lower slopes in the Allegheny and Catskill Mountains. One of these, which occupied a few square rods in a ravine bottom, was 40 years old and contained about 12 thrifty trees per square rod, the dominant ones 30 feet high and 3 inches in diameter. The stand was very dense, and there were many small dead trees which had been killed by the shade.

RATE OF GROWTH.

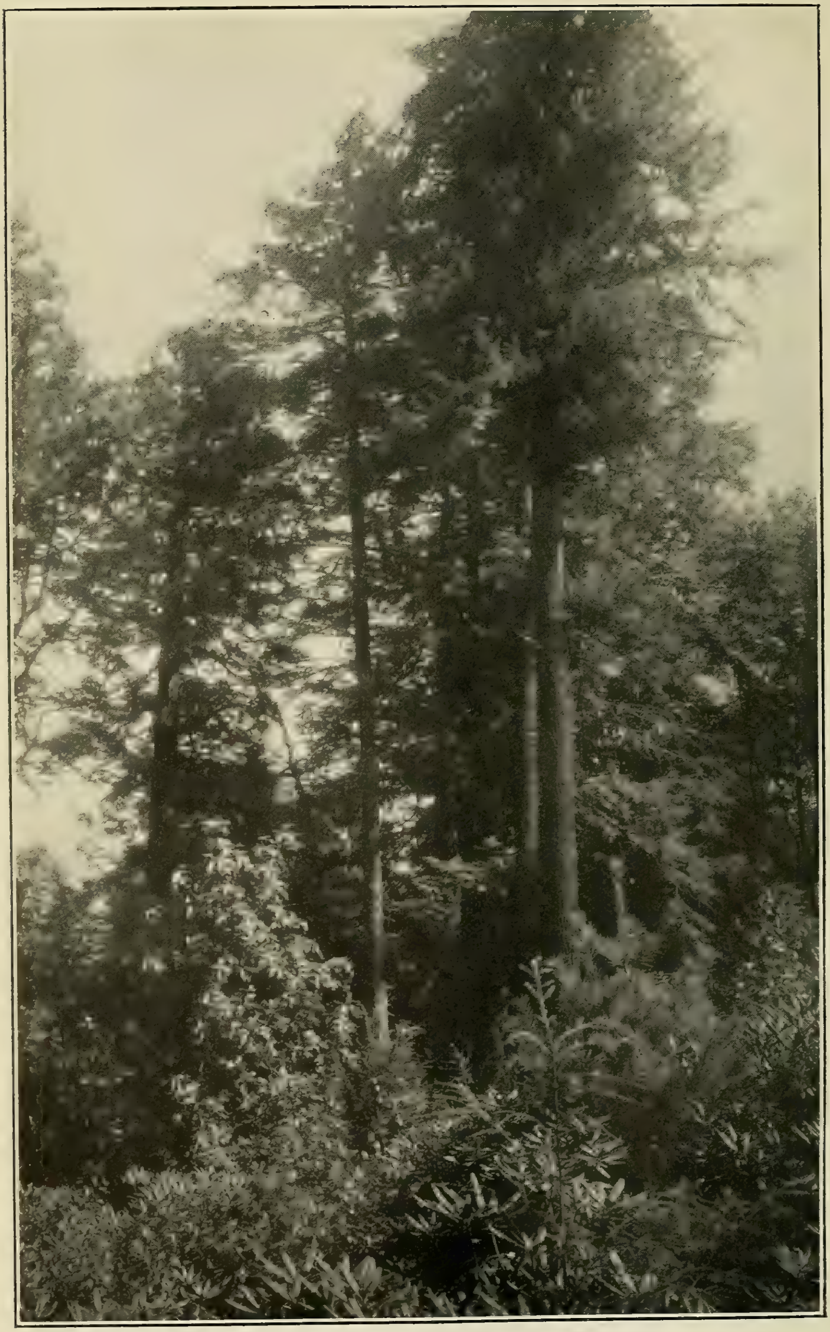
Under the shade of the mature forest the growth of the average hemlock is extremely slow. The period of suppression commonly lasts from 30 to 70 years, but if the shade remains dense it may continue for more than 200 years. Even at an advanced age, however, a suppressed tree will respond to an increase in its light supply by a proportionate increase in its height growth. If it ultimately attains a dominant position in the stand with plenty of light, it will grow fairly rapidly in diameter and volume.

Individual hemlocks show a wide variation in rate of growth, according to the amount of light they receive. Trees of the same diameter in the same stand may differ in age by more than a century. The average growth of hemlock obtained from measurements of many individual trees therefore represents many different degrees of suppression and does not indicate what a tree would do if given full light. The maximum growth, similarly obtained, more closely resembles the growth of a tree in the open, though even here the retarding influence of suppression is felt to some extent.

[1] Cf. "Roots of the Hemlock," by S. H. Harlow, in Jour. N. Y. Bot. Gard., July, 1900, Vol. I, No. 7, 100-101.



THE STORY OF THIS POLE STAND OF HEMLOCK IS TOLD BY THE WHITE PINE STUMPS IN THE FOREGROUND.



GROUP OF MATURE HEMLOCK, MITCHELL COUNTY, N. C., SHOWING HEMLOCK AND PINE REPRODUCTION COMPETING WITH RHODODENDRON.

Local variations in growth are also caused by climate and the quality, depth, drainage, and moisture of the soil. Growth is most rapid on the best soils. Hemlock is especially favored by a temperate, humid climate and long growing season, combined with moist but well-drained soils—conditions which it finds in the coves and slopes of the southern Appalachians.

Tables 8 to 11 show the growth of hemlock in localities in various parts of its range. The tables give the maximum, minimum, and average rates of growth in height, diameter, and volume, and are based on measurements of many forest-grown trees differing widely in amount of suppression. Though not based on crown-class distinctions, the maximum figures may safely be regarded as representing the average growth of dominant trees on good soil, and the minimum that of suppressed trees which have reached merchantable size. The average figures, however, may represent the growth both of trees of the middle crown classes and of dominant trees in situations of poor quality. These data were averaged separately for diameters, heights, and volumes, so that only an approximate relation exists between the values for any given age. Furthermore, the variation in height and volume among trees of a given diameter is considerable, as shown by the volume tables in the Appendix.

TABLE 8.—*Growth of hemlock in Leelanau County, Mich.*[1]

Age.	Diameter, breast-high.			Height.			Volume.				
	Inches.			Feet.			Cubic feet.			Board feet.	
	Minimum.	Average.	Maximum.	Minimum.	Average.	Maximum.	Minimum.	Average.	Maximum.	Average.	Maximum.
Years.											
20	0.3	0.7	2.0	6	8	18	....	....	....	....	....
30	.6	1.3	3.9	7	12	31	....	....	....	....	....
40	.9	2.1	5.7	8	16	42	....	....	2.2	....	....
50	1.3	2.9	7.6	10	20	53	....	....	6.6	....	13
60	1.6	3.8	9.4	11	25	62	....	....	12.4	....	31
70	2.0	4.7	11.1	13	30	70	....	....	20.0	....	56
80	2.4	5.7	12.8	14	35	76	....	1.8	29.0	....	80
90	2.7	6.7	14.5	15	40	82	....	3.6	39.0	....	130
100	3.1	7.8	16.1	17	44	85	....	5.9	50.0	7	180
110	3.4	9.0	17.7	18	49	88	....	9.2	64.0	20	240
120	3.8	10.0	19.4	20	53	91	....	12.5	78.0	35	320
130	4.3	11.2	21.0	21	57	94	....	17.1	94.0	50	410
140	4.8	12.3	22.6	23	60	96	....	22.0	112.0	67	500
150	5.3	13.4	24.2	25	63	98	1.0	28.0	131.0	86	600
160	5.9	14.5	25.7	27	66	100	1.8	34.0	152.0	110	700
170	6.6	15.5	27.2	29	68	102	2.6	40.0	174.0	130	810
180	7.3	16.5	....	31	70	....	3.4	47.0	....	150	910
190	8.0	17.5	....	33	72	....	4.6	54.0	....	180	1,020
200	8.7	18.4	....	35	74	....	5.9	61.0	....	210	1,130

[1] Based on measurements of 186 trees, 109 to 325 years old, made by S. J. Record in 1905.

TABLE 9.—*Growth of hemlock in the Southern Appalachian Mountains.*[1]

Age.	Diameter breast-high—inches.					Height—feet.				
	All types.		Slope type.		Cove type.	All types.		Slope type.		Cove type.
			West Virginia.	Tennessee.	North Carolina.			West Virginia.	Tennessee.	North Carolina.
	Minimum.	Maximum.	Average.	Average.	Average.	Minimum.	Maximum.	Average.	Average.	Average.
Years.										
20	0.1	4.0	0.4	0.2	....	....	29	....	....	....
30	.7	6.7	.9	.9	1.1	9	41	....	9	15
40	1.2	9.0	1.3	1.9	2.2	11	53	11	16	23
50	1.8	11.2	1.9	3.0	3.4	14	63	14	23	30
60	2.3	13.1	2.4	4.1	4.7	16	71	17	30	36
70	2.8	15.0	2.9	5.3	6.2	19	79	20	37	42
80	3.3	16.9	3.6	6.7	7.6	21	86	24	44	47
90	3.8	18.8	4.2	8.0	9.1	23	92	27	51	53
100	4.3	20.6	4.9	9.4	10.5	25	98	31	58	58
110	4.8	22.5	5.6	10.7	11.9	28	103	34	64	62
120	5.2	24.3	6.4	11.8	13.2	30	107	39	69	66
130	5.6	26.2	7.3	12.9	14.5	32	111	43	73	70
140	6.0	28.0	8.1	14.0	15.5	34	114	47	77	73
150	6.4	30.0	8.9	15.1	16.5	35	117	51	81	76
160	6.8	31.9	9.9	16.1	17.4	37	120	56	84	78
170	7.2	33.8	10.9	17.1	18.3	39	122	60	87	81
180	7.6	35.7	11.9	18.1	19.2	41	125	64	90	83
190	8.0	37.5	12.7	19.1	20.0	43	127	67	93	85
200	8.3	39.5	13.5	20.0	20.7	44	129	70	95	87

Age.	Volume—cubic feet.					Volume—board feet.			
	All types.		Slope type.		Cove type.	All types.	Slope type.		Cove type.
			West Virginia.	Tennessee.	North Carolina.		West Virginia.	Tennessee.	North Carolina.
	Minimum.	Maximum.	Average.	Average.	Average.	Maximum.	Average.	Average.	Average.
Years.									
20	....	....	....	....	....	....	....	....	....
30	....	3.8	....	....	....	....	....	....	....
40	....	10.3	....	....	....	4	....	....	....
50	....	19.7	....	....	....	30	....	....	....
60	....	31.0	....	....	....	68	....	....	....
70	....	45.0	....	1.5	3.1	120	....	....	....
80	....	62.0	....	4.2	6.2	180	....	....	....
90	....	82.0	....	8.0	10.5	260	....	....	....
100	....	105.0	....	12.4	15.9	350	....	....	14
110	....	130.0	1.7	17.9	22.0	450	....	20	34
120	1.2	157.0	3.0	24.0	29.0	580	....	39	56
130	1.6	188.0	4.8	31.0	36.0	730	....	60	79
140	2.2	220.0	7.0	38.0	44.0	910	....	85	100
150	2.8	257.0	10.0	46.0	52.0	1,130	....	110	130
160	3.5	297.0	13.5	54.0	60.0	1,380	10	150	160
170	4.3	340.0	17.7	64.0	68.0	1,650	22	190	200
180	5.2	381.0	22.0	74.0	77.0	1,920	39	230	250
190	6.1	422.0	27.0	86.0	86.0	2,170	58	270	300
200	7.1	460.0	32.0	98.0	94.0	2,400	80	310	350

[1] Based on the following data, collected by Walter Mulford, 1905–1906:
West Virginia, Greenbrier County .... 47 trees, 137 to 200 years old.
Tennessee, Johnson County .... 131 trees, 111 to 200 years old.
North Carolina, Mitchell County .... 308 trees, 89 to 200 years old.

TABLE 10.—*Growth of hemlock in Otsego County, N. Y.*[1]

Age.	Diameter breast-high.			Height.			Volume.			
	Inches.			Feet.			Cubic feet.		Board feet.	
	Minimum.	Average.	Maximum.	Minimum.	Average.	Maximum.	Average.	Maximum.	Average.	Maximum.
Years.										
20	....	0.4	1.5	....	7	17	....	....	....	....
30	0.1	.9	2.9	5	10	28	....	....	....	....
40	.3	1.4	4.4	6	13	39	....	....	....	....
50	.5	1.9	5.9	7	16	49	....	2.8	....	....
60	.7	2.5	7.4	8	20	58	....	6.4	....	....
70	.9	3.3	8.9	9	24	66	....	11.4	....	30
80	1.1	4.0	10.5	10	28	73	....	18.1	....	55
90	1.3	4.7	12.1	11	32	79	....	26.0	....	86
100	1.5	5.5	13.8	13	36	84	1.7	36.0	....	120
110	1.9	6.4	15.4	15	40	88	3.1	47.0	....	170
120	2.1	7.3	17.1	16	45	91	5.0	60.0	....	230
130	2.4	8.3	18.7	17	50	94	7.9	75.0	16	300
140	2.7	9.4	20.4	19	54	97	11.1	91.0	29	380
150	3.0	10.5	22.1	20	59	100	15.5	108.0	44	480
160	3.3	11.6	23.9	22	63	102	20.0	126.0	61	590
170	3.7	12.7	25.7	23	66	105	24.0	145.0	80	710
180	4.1	13.5	27.4	25	69	....	29.0	....	100	850
190	4.4	14.3	29.1	27	71	....	34.0	....	120	1,000
200	4.9	15.1	30.9	29	72	....	39.0	....	140	1,150

[1] Based on measurements of 176 trees, 48 to 420 years old, made by J. G. Peters in 1902.

TABLE 11.—*Growth of hemlock in Vermont.*[2]

(Average.)

Age.	Diameter breast-high.	Volume.
Years.	*Inches.*	*Bd. ft.*
130	7.0	....
140	8.0	34
150	9.0	48
160	10.2	69
170	11.4	100
180	12.6	140
190	13.9	180
200	15.2	230

[2] Data contained in Vermont Experiment Station Bulletin 161, "Hemlock in Vermont," by A. F. Hawes. Volumes scaled by Vermont rule.

SUSCEPTIBILITY TO INJURY.

As before stated, hemlock is extremely sensitive to sudden changes in the density of the forest. Middle-aged and full-grown trees appear to be the most susceptible.

The most destructive of the insect enemies of hemlock is the flat-headed eastern hemlock bark borer, *Melanophila fulvoguttata* Harr. According to Mr. H. E. Burke[3] this insect "has caused the death of

[3] "Injuries to forest trees by flat-headed borers." Yearbook of the Department of Agriculture, 1909; pp. 405–406. See also following articles by Dr. A. D. Hopkins:

"Catalogue of exhibits of insect enemies of forest and forest products, etc.," Bul. 48, Bureau of Entomology, U. S. Department of Agriculture, 1904, p. 38.

"On the study of forest entomology in America," Bul. 37, Bureau of Entomology, 1902, p. 22.

a large amount of hemlock timber throughout the Appalachian and Northeastern States. It mines the bark on living, injured, and dying trees and kills them outright or hastens their death." Whenever large quantities of hemlock are found to be dying, search should be made for the work of this insect, and, if found, special advice in regard to combating it should be obtained from the Bureau of Entomology, Division of Forest Insects.

Hemlock is comparatively free from serious parasitic fungous diseases. Damping-off, the great enemy of many conifers in the seedling stage, is almost unknown with this species. While there are several diseases of the living tree, they seem never to occur in serious epidemics. This is no doubt largely due to the fact that the tree usually grows in mixed stands. The timber when cut is very susceptible to decay, and a large number of saprophytic fungi attack it.[1]

The shallow-rootedness of hemlock makes it very susceptible to fire. A ground fire which burns through the humus will usually kill hemlock trees, though deeper-rooted species may escape with slight injury. Even a severe surface fire may dry out the humus or damage the roots sufficiently to kill the tree outright, or at least to lay it open to attack by fungi and insects. Severe crown fires are invariably fatal. Fires of all kinds are most to be feared after logging operations in adjacent timber, when the ground is covered with the dry and highly inflammable tree tops and branches. The best safeguard is to burn this débris under conditions making it impossible for the fire to escape. The danger can be lessened by lopping away all branches from the tops, and either piling them or scattering them close to the ground.

Because of its relatively short, stout, tapering trunk, hemlock is less subject to windfall than its shallow root system would lead one to expect. Where it grows as an understory among taller neighbors it is rarely thrown except by winds strong enough to overthrow all species alike. Severe damage is often done, however, to stands consisting principally of hemlock, especially when located on shallow soil and in situations exposed to the wind. In September, 1896, a heavy storm near Wilkes-Barre, Pa., blew down over 6,000,000 feet of hemlock in one tract, and similar cases are not uncommon. Where the roots are fairly secure, the trunk or the crown may be snapped off by severe winds.

The most common and in the aggregate the worst injury to hemlock from wind is the so-called "wind-shake," which is a separation of the rings of wood caused by the tree being rocked back and forth. Wind-shake is always found in the butt, which is thereby rendered

[1] This paragraph regarding diseases was prepared by Perley Spaulding, pathologist, Investigations in Forest Pathology, Bureau of Plant Industry. Further information on fungous injury to hemlock is contained in "Diseases of the eastern hemlock," by Dr. Spaulding, in Proc. Society of American Foresters Vol. IX, No. 2, pp. 245–256.

SUPPRESSED HEMLOCK SAPLINGS IN A MATURE STAND OF HEMLOCK.

These will fill openings left by the removal of old trees, but too sudden an opening of the stand will kill them.

unfit for lumber. In connection with the prevailing "butt rot," this has made necessary the custom of cutting high stumps and sawing off the butts until they reveal solid wood. Where there is a market for pulpwood, high stumps and butts left in the woods represent a great deal of unnecessary waste.

HEMLOCK IN FOREST MANAGEMENT.

Hemlock grows too slowly and is of too little commercial value to be recommended for planting or for encouragement among natural second growth as a timber tree. An understory of hemlock, however, like one of spruce or fir, is useful for soil protection, especially in stands of oak, chestnut, pine, and other species, when these do not themselves cast a sufficiently heavy shade. As a decorative tree for parks it is very desirable, and its heavy foliage and shade endurance give it exceptional value for the protection of stream sources.

The management of hemlock will ultimately be restricted to lands useless not only for agriculture but also for growing many kinds of commercial timber. Poorly accessible mountain lands, where logging is difficult and expensive, can well be devoted to raising hemlock and other slow-growing timber through long rotations and to large sizes. The expense entailed by such a procedure, however, will ordinarily be too great to warrant private investment, and the management will therefore be a State problem. In such places lumber production will tend to become secondary to protection as an object of management.

Hemlock's tolerance of shade adapts it for growth as a subordinate stand among other kinds of timber. In such cases it materially increases the yield per acre and at the same time protects and enriches the forest soil, thereby tending to accelerate the growth of the other species.

To increase the proportion and accelerate the growth of hemlock in the mixed stands where it is now found, the selection ("single-tree") method of management is best. This involves the removal at stated intervals of scattered mature trees or small groups of trees, and should not open up the stand enough to endanger it from windfall or from too sudden access of light and air. On steep slopes the cutting must be especially light, to prevent erosion. Besides accelerating the growth of the hemlock understory by admitting light, the system also insures a constant growth of timber without the long, unproductive period of reestablishment which follows clear cutting. In all selection cutting the branches should be lopped and scattered.

Pure or nearly pure hemlock second growth should be thinned very lightly and often, so as to insure to each tree a good supply of light and growing space. Additional thinnings should be made whenever the crowns close together.

A great deal of the remaining old-growth hemlock timber occupies fertile soil, suitable either for agriculture or for raising timber crops of rapid-growing species. The expense of selection cuttings to favor hemlock on lands of this quality is not warranted. Clear cutting, therefore, is the best in such cases. Attempts to secure hemlock reproduction in the ensuing second growth, however, are obviously out of place. Unless the land is claimed for cultivation, some of the more rapid growing species which appear in the second growth are usually of more promise as the principal crop.

The management of hemlock on level lands thus becomes a problem of the best use of the existing timber, with no special effort to secure hemlock reproduction. What constitutes best use is determined by market and labor conditions in any given region. The utilization of all species constantly becomes more intensive, and the premium once placed on waste both in the woods and at the mill is growing less as new uses are introduced and the value of wood increases. Paper-pulp and fiber-board manufacture has presented good opportunities for profitably disposing of waste. In some regions hemlock is going into pulp instead of lumber. It is in connection with pulpwood logging that tanbark gathering can be done most economically, since peeled logs are more suitable for pulp and less suitable for lumber than unpeeled. The use of hemlock for pulp has the further advantage that it includes crooked and small logs of little or no value for lumber and of knotty tops and broken and defective logs that would otherwise be left in the woods to rot. Quantities of hemlock slabs are now sold to pulp mills by sawmills; but much low-grade hemlock lumber is still produced, the value of which is often less than that of an equal wood volume made into pulp. Among the economies of the future one of the most important will be a closer discrimination between logs and portions of logs which will make high-grade lumber and those which will pay better for pulp.

APPENDIX.

Tables 12 to 15 show the volumes of average hemlock trees, in board feet, Scribner rule, in the Lake States and the Southern Appalachian region. These are based both on the total height of the tree and on the number of logs. Table 16 gives both the cubic-foot and the board-foot volumes (by actual measurement, not by log scale) of small-sized hemlock in northern New Hampshire. Table 17 gives the merchantable cubic volume of hemlock (including bark) in the Lake States. Cubic volumes may be reduced roughly to cords by dividing by 90. The volume without bark can be obtained approximately by deducting 19 per cent from the total volume for Lake States figures and the following per cents for Southern Appalachian measurements:

Diameter breast-high.	Bark volume in proportion to total volume
Inches.	*Per cent.*
6–9	15
10–15	17
16–21	18
22–27	19

TABLE 12.—*Volume of hemlock, in board feet, Wisconsin (Marinette and Vilas Counties) and Michigan (Gogebic County).*

[Based on total height of tree. Scaled by the Scribner rule.]

Diameter breast-high.	Height of tree—feet. 30	40	50	60	70	80	90	100	Diameter inside bark of top.	Basis.
	Volume—board feet.									
Inches.									*Inches.*	*Trees.*
8	5	7	13	20	25	30	....	....	6	53
9	8	14	22	29	35	40	....	....	6	72
10	12	22	32	40	47	52	....	....	6	56
11	16	29	42	51	60	67	75	....	6	53
12	20	37	53	64	76	84	93	....	7	46
13	25	46	65	78	94	100	110	....	7	35
14	30	56	77	95	110	130	140	....	7	18
15	36	65	90	110	130	150	160	....	8	31
16	41	76	110	130	160	180	190	200	8	25
17	......	87	120	150	180	210	220	240	8	30
18	......	100	140	180	210	240	260	280	8	14
19	......	......	160	200	240	280	300	320	9	16
20	......	......	180	230	280	310	340	360	9	20
21	......	......	200	260	310	350	380	410	9	11
22	......	......	220	290	350	390	430	470	10	13
23	......	......	......	330	380	440	480	520	10	4
24	......	......	......	360	420	490	540	580	10	6
25	......	......	......	390	460	530	600	650	10	9
26	......	......	......	430	510	580	660	720	11	4
27	......	......	......	470	550	640	720	790	11	8
28	......	......	......	500	590	690	780	870	11	6
29	......	......	......	540	640	750	850	940	11	3
30	......	......	......	570	680	800	920	1,030	12	1

TABLE 12.—*Volume of hemlock, in board feet, Wisconsin (Marinette and Vilas Counties) and Michigan (Gogebic County)*—Continued.

Diameter breast-high.	Height of tree—feet.								Diameter inside bark of top.	Basis.
	30	40	50	60	70	80	90	100		
	Volume—board feet.									
Inches.									*Inches.*	*Trees.*
31	......	......	......	......	720	860	990	1,110	12	2
32	......	......	......	......	760	930	1,070	1,200	12	1
33	......	......	......	......	810	990	1,140	1,290	12	3
34	......	......	......	......	850	1,050	1,220	1,380	13	1
35	......	......	......	......	......	1,120	1,300	1,480	13	1
36	......	......	......	......	......	1,180	1,380	1,570	13	....
37	......	......	......	......	......	....	1,470	1,670	13	....
38	......	......	......	......	......	....	1,550	1,780	14	....
										542

Scaled from taper curves, mostly in 16.3-foot logs, with a few shorter logs. Stump height, 2 feet.

TABLE 13.—*Volume of hemlock, in board feet, Wisconsin (Marinette and Vilas Counties) and Michigan (Gogebic County).*

[Based on number of 16-foot logs per tree. Scaled by the Scribner rule.]

Diameter breast-high.	Number of 16-foot logs.									Diameter inside bark of top.	Basis.
	1	1½	2	2½	3	3½	4	4½	5		
	Volume—board feet.										
Inches.										*Inches.*	*Trees.*
8	18	28	38	......	......	....	....	....	....	6	53
9	19	30	42	......	......	....	....	....	....	6	72
10	20	32	47	60	......	....	....	....	....	6	56
11	23	39	57	72	......	....	....	....	....	6	53
12	25	45	66	86	110	....	....	....	....	7	46
13	26	53	79	100	130	....	....	....	....	7	35
14	28	63	92	120	140	170	....	....	....	7	18
15	30	72	110	130	170	200	....	....	....	8	31
16	32	82	120	150	190	220	....	....	....	8	25
17	34	94	140	180	210	250	....	....	....	8	30
18	36	110	160	200	240	280	320	....	....	8	14
19	38	120	180	220	270	310	350	....	....	9	16
20	40	130	200	250	290	340	390	....	....	9	20
21	......	150	230	280	330	380	430	....	....	9	11
22	......	170	260	310	360	420	480	530	....	10	13
23	......	......	280	340	400	460	530	600	....	10	4
24	......	......	310	370	440	510	580	660	....	10	6
25	......	......	330	400	480	560	640	730	....	10	9
26	......	......	360	430	520	600	700	810	920	11	4
27	......	......	......	470	560	660	770	880	1,000	11	8
28	......	......	......	500	600	710	830	960	1,090	11	6
29	......	......	......	530	640	760	900	1,040	1,180	11	3
30	......	......	......	560	680	820	960	1,110	1,270	12	1
31	......	......	......	......	720	880	1,040	1,200	1,370	12	2
32	......	......	......	......	770	930	1,110	1,280	1,460	12	1
33	......	......	......	......	820	990	1,180	1,370	1,560	12	3
34	......	......	......	......	870	1,050	1,250	1,450	1,670	13	1
35	......	......	......	......	......	1,140	1,340	1,550	1,760	13	1
36	......	......	......	......	......	1,210	1,420	1,640	1,870	13	....
37	......	......	......	......	......	1,270	1,500	1,730	1,970	13	....
38	......	......	......	......	......	1,330	1,580	1,830	2,080	14	....
											542

Scaled from taper curves, mostly in 16.3-foot logs, with a few shorter logs. Stump height, 2 feet.

TABLE 14.—*Volume of hemlock in board feet, Southern Appalachian region.*[1]

[Based on total height of trees. Scaled by Scribner Decimal C rule.]

Diameter breast-high.	Height of tree—feet.								Height of stump.	Diameter inside bark of top.	Total basis.
	50	60	70	80	90	100	110	120			
	Volume—board feet (in tens).										
Inches.									*Feet.*	*Inches.*	*Trees.*
10	1	1	2	......	......	......	......	......	2.1	7	6
11	2	2	3	3	......	......	......	......	2.2	8	3
12	3	4	4	5	5	......	......	......	2.2	8	9
13	4	5	6	7	8	......	......	......	2.3	9	23
14	6	7	8	9	10	12	......	......	2.3	9	33
15	7	8	9	11	13	16	......	......	2.4	10	59
16	9	10	11	13	16	19	24	......	2.4	10	64
17	10	12	14	16	19	23	28	......	2.4	11	65
18	12	14	17	20	23	27	32	......	2.5	11	77
19	14	17	20	23	27	31	36	41	2.5	12	83
20	17	20	23	26	31	35	41	46	2.5	12	68
21	19	23	26	30	35	40	46	51	2.5	13	80
22	22	26	30	34	40	45	51	57	2.6	13	81
23	25	29	34	39	44	50	56	63	2.6	13	86
24	29	33	39	44	50	56	62	69	2.6	14	67
25	......	38	43	49	55	62	69	76	2.6	14	81
26	......	42	48	54	61	68	75	83	2.6	15	62
27	......	47	53	60	67	74	83	91	2.6	15	64
28	......	52	59	66	73	81	90	99	2.6	15	67
29	......	58	64	72	80	89	98	108	2.6	16	54
30	......	63	70	78	87	97	107	117	2.6	16	34
31	......	......	76	85	95	105	116	127	2.7	17	33
32	......	......	82	92	102	114	126	138	2.7	17	37
33	......	......	88	99	111	124	136	150	2.7	18	29
34	......	......	94	106	120	134	147	162	2.7	18	33
35	......	......	100	114	129	144	158	174	2.7	19	19
36	......	......	......	122	138	154	170	187	2.7	19	21
37	......	......	......	131	148	165	182	200	2.7	19	9
38	......	......	......	140	158	176	194	212	2.7	20	10
39	......	......	......	149	168	187	206	225	2.8	20	8
40	......	......	......	158	179	198	218	238	2.8	21	7
41	......	......	......	......	189	209	230	251	2.8	21	5
42	......	......	......	......	199	220	242	264	2.8	22	5
43	......	......	......	......	209	232	254	277	2.8	22	6
44	......	......	......	......	220	244	267	290	2.8	23	4
45	......	......	......	......	230	255	279	303	2.8	23	3
46	......	......	......	......	......	266	291	316	2.8	24	1
47	......	......	......	......	......	278	303	329	2.8	25	1
48	......	......	......	......	......	289	315	342	2.9	25	2
49	......	......	......	......	......	301	327	355	2.9	26	1
50	......	......	......	......	......	312	340	368	2.9	26	2
											1,402

[1] From data secured under the direction of Walter Mulford, 1905–6.

TABLE 15.—*Volume of hemlock in board feet, Southern Appalachian region.*[1]

[Based on number of 16-foot logs per tree. Scaled by Scribner rule.]

Diameter breast-high.	Number of 16-foot logs.													Diameter inside bark of top.	Basis.
	1	1½	2	2½	3	3½	4	4½	5	5½	6	6½	7		
	Volume—board feet.														
Inches.														*Inches.*	*Trees.*
8	18	29	40	52	63									6	17
9	20	33	46	61	74									6	17
10	22	38	53	71	87	100								6	19
11	24	44	64	84	100	120								6	7
12	25	50	72	97	120	140	170							7	15
13	26	58	86	110	140	170	190							7	29
14	28	64	98	130	160	190	220							7	35
15	30	73	110	150	180	220	250							8	62
16	32	83	130	170	210	250	280	310						8	71
17	34	95	150	190	240	280	320	360						8	74
18	37	110	160	210	260	310	350	400						8	71
19	40	120	180	240	290	340	400	450						9	82
20	43	130	200	260	320	380	440	500	550					9	72
21	46	140	230	290	360	420	490	550	610					9	79
22	50	160	250	320	400	470	530	610	680					10	77
23	54	180	280	360	440	510	590	660	740					10	82
24	58	200	310	400	480	560	650	730	810	890				10	70
25	61	220	340	430	530	620	700	790	880	970				10	73
26	65	240	370	470	570	670	770	870	980	1,080	1,190			11	59
27	69	250	400	510	620	720	830	930	1,050	1,170	1,300			11	66
28	73	280	440	560	670	780	890	1,010	1,130	1,270	1,410	1,550		11	56
29	77	310	480	600	720	840	960	1,090	1,230	1,370	1,510	1,660		11	46
30	80	330	510	640	770	900	1,030	1,170	1,320	1,470	1,630	1,790	1,950	12	26
31		360	550	690	820	960	1,100	1,260	1,420	1,580	1,750	1,910	2,070	12	34
32		380	590	740	880	1,030	1,180	1,350	1,520	1,700	1,870	2,060	2,240	12	29
33			630	780	930	1,090	1,260	1,440	1,630	1,820	2,010	2,200	2,390	12	14
34			660	830	990	1,160	1,340	1,530	1,730	1,930	2,150	2,360	2,580	13	25
35				880	1,050	1,230	1,420	1,630	1,840	2,050	2,270	2,490	2,710	13	19
36				930	1,110	1,300	1,500	1,710	1,940	2,170	2,410	2,650	2,890	13	12
37					1,160	1,360	1,580	1,820	2,060	2,300	2,560	2,820	3,090	13	4
38					1,210	1,430	1,670	1,910	2,160	2,420	2,700	2,960	3,250	14	9
39						1,500	1,750	2,010	2,280	2,560	2,840	3,130	3,410	14	3
40						1,570	1,840	2,120	2,400	2,690	2,980	3,270	3,550	14	3
41						1,650	1,930	2,230	2,520	2,820	3,120	3,420	3,720	14	2
42						1,710	2,020	2,320	2,640	2,960	3,280	3,600	3,930	15	2
43							2,110	2,430	2,760	3,100	3,440	3,770	4,100	15	4
44							2,200	2,540	2,900	3,250	3,600	3,960	4,310	15	
45							2,300	2,660	3,030	3,400	3,760	4,140	4,510	15	1
46							2,400	2,780	3,170	3,550	3,940	4,330	4,720	16	1
47								2,920	3,310	3,710	4,110	4,520	4,940	16	1
48								3,050	3,450	3,880	4,300	4,730	5,150	16	1
49								3,200	3,600	4,030	4,480	4,930	5,360	16	
50								3,320	3,750	4,200	4,670	5,140	5,630	17	1
															1,370

[1] From data secured under the direction of Walter Mulford, 1905–6.

TABLE 16.—*Volume of hemlock in cubic feet and board feet, southern New Hampshire.*

[Based on total height of tree.[1]]

Diameter breast-high.	Height of tree—feet. Volume of used length. 30		40		50		60		70		Number of board feet per 1 cubic foot of log.	Diameter inside bark of last log.	Basis.
Inches.	*Cu.ft.*	*Bd.ft.*	*Cu.ft.*	*Bd.ft.*	*Cu.ft.*	*Bd.ft.*	*Cu.ft.*	*Bd.ft.*	*Cu.ft.*	*Bd.ft.*		*Inches.*	*Trees.*
6	1.8	5	2.8	......	3.7	......	......	......	......	......	4.5	4.4	4
7	2.7	10	3.8	20	5.0	30	6.3	42	......	......	5.0	4.4	17
8	3.9	17	5.0	28	6.6	39	8.1	50	......	......	5.3	5.1	40
9	5.0	26	6.5	36	8.4	49	10.0	60	11.8	......	5.5	5.3	57
10	6.4	36	8.5	46	10.6	59	12.5	71	14.3	86	5.6	5.7	57
11	8.0	47	10.5	58	13.0	72	15.2	86	17.3	103	5.6	5.5	41
12	10.2	60	12.8	72	15.4	86	18.2	103	20.8	123	5.7	6.0	42
13	12.2	......	15.2	88	18.3	104	21.5	124	24.3	148	5.7	6.7	17
14	......	......	17.7	107	21.2	125	25.0	147	28.2	173	5.8	6.1	14
15	......	......	20.0	126	24.4	148	28.8	172	32.8	204	5.9	6.4	14
16	......	......	22.5	148	27.6	171	33.0	200	37.5	240	6.1	6.7	6
17	......	......	......	......	30.8	197	37.7	233	42.8	281	6.2	5.9	8
													317

[1] Prepared by C. A. Lyford and Louis Margolin, 1906. The volumes in board feet are for actual saw cut, and therefore run much higher than if they were based on log scale. The volume in cubic feet includes bark.

TABLE 17.—*Volume of hemlock in cubic feet (including bark), Wisconsin (Marinette and Vilas Counties) and Michigan (Gogebic County).*

[Based on total height of tree.]

Diameter breast-high.	Total height of tree—feet. Volume—cubic feet. 30	40	50	60	70	80	90	100	Basis.
Inches.									*Trees.*
5	1.0	1.2	1.7	....	....	....	....	....	18
6	2.0	2.6	3.3	....	....	....	....	....	16
7	3.1	4.1	5.2	5.9	....	....	....	....	28
8	4.1	5.5	7.3	8.4	....	....	....	....	53
9	5.4	7.4	9.3	10.9	12.3	....	....	....	72
10	7.0	9.5	11.9	14.1	15.7	....	....	....	56
11	8.6	11.8	14.6	17.2	19.6	22	....	....	53
12	10.6	14.4	18.0	21.0	24.0	26	....	....	46
13	12.5	17.0	21.0	24.0	28.0	31	33	....	35
14	14.8	20.0	24.0	28.0	33.0	37	39	....	18
15	17.0	23.0	28.0	33.0	38.0	42	45	....	31
16	19.3	26.0	32.0	38.0	44.0	48	51	54	25
17	....	....	36.0	43.0	50.0	54	59	62	30
18	....	....	41.0	48.0	56.0	61	67	71	14
19	....	....	45.0	54.0	62.0	69	75	79	16
20	....	....	50.0	60.0	69.0	77	83	87	20
21	....	....	....	66.0	76.0	85	91	98	11
22	....	....	....	72.0	83.0	93	100	109	13
23	....	....	....	79.0	91.0	102	109	119	4
24	....	....	....	85.0	99.0	111	119	129	6
25	....	....	....	....	107.0	120	131	143	9
26	....	....	....	....	116.0	130	144	156	4
27	....	....	....	....	123.0	139	155	169	8
28	....	....	....	....	131.0	147	167	182	6
29	....	....	....	....	....	157	179	195	3
30	....	....	....	....	....	169	191	208	1
31	....	....	....	....	....	180	204	222	2
32	....	....	....	....	....	192	218	237	1
33	....	....	....	....	....	....	231	252	3
34	....	....	....	....	....	....	246	267	1
35	....	....	....	....	....	....	260	283	1
36	....	....	....	....	....	....	275	299	....
									604

Based on taper curves. Volume includes stem with bark between a 2-foot stump and a 4-inch top. Bark forms 19 per cent of the total volume of the stem.

Table 18 shows the average amount of bark obtainable per 1,000 board feet from hemlock trees of different sizes in the Southern Appalachians.

TABLE 18.—*Cords of bark per 1,000 board feet (Doyle-Scribner) for hemlock trees of different sizes in the Southern Appalachians.*[1]

Diameter breast-high.	Cords per 1,000 board feet.	Diameter breast-high.	Cords per 1,000 board feet.	Diameter breast-high.	Cords per 1,000 board feet.
Inches.		*Inches.*		*Inches.*	
12	2.8	18	1.1	25	0.6
13	2.3	19	1.0	26	.6
14	1.9	20	.9	27	.5
15	1.6	21	.8	28	.5
16	1.3	22	.8	29	.5
17	1.2	23	.7	30	.4
....	....	24	.7	....	....

[1] From data secured under the direction of Walter Mulford, 1905-6.

TABLE 19.—*Volume of hemlock bark, in cords, for trees over and under 100 feet in height, Southern Appalachian region.*[1]

Diameter breast-high.	Trees 100 feet and under.	Trees 100 feet and over.	Basis.	Diameter breast-high.	Trees 100 feet and under.	Trees 100 feet and over.	Basis.
	Volume of bark.				Volume of bark.		
Inches.	*Cord.*	*Cord.*	*Trees.*	*Inches.*	*Cord.*	*Cord.*	*Trees.*
10	0.10	....	1	31	0.42	0.48	26
11	.11	....	1	32	.43	.50	18
12	.11	....	2	33	.45	.52	23
13	.12	....	5	34	.47	.55	20
14	.13	....	12	35	.48	.57	14
15	.14	0.18	14				
				36	.50	.59	14
16	.15	.19	20	37	.52	.62	8
17	.17	.21	30	38	.53	.64	11
18	.19	.23	35	39	.55	.67	5
19	.21	.25	33	40	.56	.69	5
20	.23	.26	28				
				41	.58	.72	4
21	.25	.28	36	42	.60	.75	6
22	.27	.30	35	43	....	.78	1
23	.29	.32	50	44	....	.81	....
24	.30	.34	30	45	....	.84	1
25	.32	.36	36				
				46	....	.87	2
26	.34	.38	33	47	....	.91	2
27	.35	.40	38	48	....	.94	2
28	.37	.42	32				
29	.39	.44	22				682
30	.40	.46	27				

[1] Prepared under the direction of Walter Mulford, 1905-6.

TABLE 20.—*Volume of hemlock bark in stacked cords—Vermont.*[1]

Diameter breast-high.	Volume of bark.	Diameter breast-high.	Volume of bark.
Inches.	*Cord.*	*Inches.*	*Cord.*
8	0.03	21	0.25
9	.05	22	.28
10	.06	23	.31
11	.07	24	.34
12	.08	25	.37
13	.09	26	.40
14	.10	27	.43
15	.12	28	.46
16	.14	29	.50
17	.16		
18	.18		
19	.20		
20	.22		

[1] From "Hemlock in Vermont," by A. F. Hawes, State forester; Vt. Agr. Exp. Sta. Bulletin 161 (January, 1912), p. 8. The table was constructed by "subtracting the volumes of the trees inside the bark from their volumes outside the bark, and multiplying by 0.4, on the assumption that 40 per cent of an average stacked cord of bark is solid bark." The accuracy of this factor (taken from Schenck's "Forest Mensuration," 1905, p. 14) was borne out by investigations of a few piles of bark.

The following taper tables give diameters inside bark at different heights for average hemlock trees of various sizes in the Lake States and Southern Appalachians. The distances from the ground are in units of 8.15 feet above a 2-foot stump. These units represent the half of a 16.3-foot log. The practical use of these tables is to permit scaling trees of given size in terms of any desired log rule, but they also serve as a basis for comparing hemlock with other species in regard to form. The tables were prepared from existing measurements by W. B. Barrows.

TABLE 21.—*Diameters inside bark at different heights above the ground for trees of different sizes, based on measurements of 614 trees in Wisconsin (Marinette and Vilas Counties) and Michigan (Gogebic County).*

[The heights above ground represent 16.3-foot logs and half logs, plus a stump height of 2 feet.]

Diameter breast-high outside bark.	30-foot trees.		40-foot trees.			50-foot trees.				60-foot trees.					
	Height above ground—feet.														
	10.15	18.3	10.15	18.3	26.45	10.15	18.3	26.45	34.6	10.15	18.3	26.45	34.6	42.75	50.9
	Diameter inside bark—inches.														
Inches.															
4	3.0	1.4	3.1	2.4	1.6	......	......	......	......	......	......	......	......	......	....
5	3.9	2.0	3.9	3.1	2.1	......	......	......	......	......	......	......	......	......	....
6	4.7	2.5	4.8	3.9	2.6	5.3	4.5	3.6	2.4	......	......	......	......	......	....
7	5.6	3.2	5.7	4.7	3.1	6.1	5.3	4.1	2.8	6.0	5.5	4.7	3.6	2.4	1.3
8	6.4	3.9	6.6	5.3	3.6	6.9	6.1	4.8	3.2	6.8	6.2	5.3	4.2	2.9	1.5
9	7.4	4.5	7.5	6.0	4.1	7.7	6.8	5.4	3.6	7.6	6.9	6.1	4.8	3.3	1.7
10	8.1	5.1	8.3	6.8	4.6	8.5	7.6	6.1	4.0	8.5	7.8	6.8	5.4	3.7	2.0
11	......	......	9.2	7.5	5.1	9.3	8.3	6.6	4.4	9.2	8.5	7.5	6.0	4.1	2.2
12	......	......	10.0	8.2	5.7	10.1	9.0	7.3	4.8	10.0	9.5	8.3	6.6	4.6	2.4
13	......	......	10.9	8.9	6.2	10.9	9.8	7.8	5.2	10.8	10.1	9.0	7.2	5.0	2.6
14	......	......	11.8	9.6	6.8	11.6	10.5	8.5	5.6	11.6	10.9	9.7	7.8	5.5	2.9
15	......	......	12.7	10.3	7.3	12.3	11.2	9.0	6.0	12.5	11.6	10.4	8.4	5.9	3.2
16	......	......	......	......	......	13.0	11.9	9.7	6.4	13.3	12.5	11.1	9.0	6.4	3.6
17	......	......	......	......	......	13.8	12.6	10.2	6.9	14.1	13.2	11.8	9.5	6.8	3.7
18	......	......	......	......	......	14.5	13.3	10.8	7.3	14.8	14.1	12.5	10.1	7.3	4.1
19	......	......	......	......	......	......	......	......	......	15.7	14.9	13.2	10.7	7.7	4.4
20	......	......	......	......	......	......	......	......	......	16.4	15.7	13.9	11.3	8.2	4.7
21	......	......	......	......	......	......	......	......	......	17.2	16.5	14.7	11.9	8.6	4.8
22	......	......	......	......	......	......	......	......	......	17.9	17.3	15.4	12.5	9.0	5.0

TABLE 21.—*Diameters inside bark at different heights above the ground for trees of different sizes, based on measurements of 614 trees in Wisconsin (Marinette and Vilas Counties) and Michigan (Gogebic County)*—Continued.

Diameter breast-high outside bark.	70-foot trees.							80-foot trees.							
	Height above ground—feet.														
	10.15	18.3	26.45	34.6	42.75	50.9	59.05	10.15	18.3	26.45	34.6	42.75	50.9	59.05	67.2
	Diameter inside bark—inches.														
Inches.															
9	7.7	7.1	6.4	5.5	4.3	3.0	1.5								
10	8.5	7.9	7.1	6.1	4.9	3.5	1.9								
11	9.3	8.6	7.9	6.8	5.5	3.9	2.2	9.3	8.7	8.1	7.4	6.4	5.1	3.6	2.1
12	10.1	9.4	8.5	7.4	6.1	4.3	2.5	10.2	9.4	8.8	8.1	7.1	5.6	4.0	2.3
13	10.9	10.2	9.3	8.2	6.7	4.8	2.7	11.0	10.2	9.5	8.7	7.6	6.2	4.4	2.5
14	11.7	10.9	10.1	8.8	7.2	5.3	3.0	11.8	11.0	10.3	9.4	8.3	6.7	4.8	2.6
15	12.5	11.7	10.8	9.5	7.8	5.7	3.3	12.5	11.7	11.1	10.1	8.8	7.3	5.2	3.0
16	13.2	12.4	11.6	10.2	8.4	6.2	3.6	13.3	12.4	11.7	10.8	9.5	7.8	5.6	3.3
17	14.0	13.1	12.3	10.9	8.9	6.6	3.9	13.9	13.2	12.5	11.5	10.1	8.3	6.1	3.6
18	14.7	13.8	13.0	11.6	9.6	7.1	4.1	14.6	13.9	13.2	12.2	10.7	8.9	6.5	3.8
19	15.4	14.5	13.6	12.2	10.1	7.5	4.3	15.4	14.7	14.0	12.9	11.4	9.5	7.0	4.1
20	16.2	15.1	14.4	12.9	10.7	7.9	4.6	16.1	15.3	14.7	13.6	12.1	10.0	7.4	4.4
21	16.9	15.9	15.1	13.6	11.3	8.4	4.8	16.9	16.0	15.3	14.3	12.7	10.6	7.8	4.7
22	17.6	16.4	15.8	14.3	11.9	8.8	5.1	17.6	16.7	16.0	15.0	13.3	11.1	8.2	4.9
23	18.3	17.3	16.4	14.9	12.5	9.3	5.3	18.3	17.4	16.7	15.7	14.0	11.7	8.7	5.2
24	19.0	17.8	17.1	15.5	13.1	9.7	5.6	19.0	18.0	17.3	16.4	14.7	12.3	9.0	5.4
25	19.7	18.5	17.7	16.1	13.6	10.1	5.8	19.8	18.8	18.1	17.1	15.4	12.9	9.5	5.6
26	20.4	19.2	18.3	16.8	14.2	10.5	6.0	20.5	19.4	18.7	17.7	16.0	13.4	9.9	5.9
27	21.1	19.8	18.9	17.4	14.8	10.9	6.2	21.2	20.1	19.5	18.5	16.6	14.1	10.3	6.1
28	21.9	20.4	19.4	18.0	15.3	11.4	6.4	21.9	20.7	20.0	19.1	17.3	14.6	10.7	6.3
29								22.7	21.4	20.7	19.8	18.0	15.2	11.1	6.6
30								23.3	22.0	21.3	20.5	18.7	15.8	11.5	6.8
31								24.1	22.7	22.0	21.1	19.4	16.5	12.0	7.1
32								24.7	23.3	22.6	21.8	20.1	17.0	12.4	7.3

Diameter breast-high outside bark.	90-foot trees.									100-foot trees.									
	Height above ground—feet.																		
	10.15	18.3	26.45	34.6	42.75	50.9	59.05	67.2	75.35	10.15	18.3	26.45	34.6	42.75	50.9	59.05	67.2	75.35	83.5
	Diameter inside bark—inches.																		
Inches.																			
13	11.0	10.2	9.6	8.7	7.7	6.7	5.3	3.9	2.4										
14	11.7	10.9	10.3	9.5	8.5	7.3	5.8	4.3	2.6										
15	12.5	11.7	11.1	10.2	9.2	8.0	6.4	4.6	2.9										
16	13.2	12.4	11.7	10.9	9.9	8.6	6.9	5.0	3.1	12.6	11.7	11.3	11.0	10.4	9.3	7.9	6.4	4.9	3.3
17	14.0	13.1	12.5	11.7	10.6	9.3	7.5	5.4	3.3	13.4	12.6	12.2	11.8	11.1	10.0	8.5	6.9	5.3	3.5
18	14.7	13.9	13.2	12.4	11.3	9.9	8.0	5.8	3.6	14.3	13.4	12.9	12.5	11.7	10.6	9.1	7.5	5.7	3.7
19	15.4	14.6	13.9	13.1	12.0	10.6	8.5	6.2	3.9	15.1	14.2	13.7	13.3	12.4	11.2	9.7	8.0	6.0	4.0
20	16.1	15.3	14.7	13.9	12.8	11.2	9.1	6.6	4.1	15.8	15.0	14.6	14.0	13.1	11.8	10.3	8.5	6.4	4.2
21	16.9	16.0	15.4	14.6	13.4	11.8	9.7	7.0	4.3	16.7	15.9	15.3	14.7	13.7	12.4	10.9	9.0	6.7	4.4
22	17.6	16.7	16.1	15.3	14.1	12.4	10.3	7.4	4.6	17.5	16.7	16.1	15.4	14.4	13.0	11.5	9.5	7.1	4.6
23	18.3	17.5	16.8	16.0	14.8	13.1	10.8	7.9	4.9	18.3	17.5	16.9	16.1	15.0	13.7	12.1	10.0	7.5	4.8
24	19.0	18.1	17.5	16.7	15.5	13.7	11.3	8.3	5.1	19.1	18.3	17.6	16.8	15.7	14.4	12.7	10.5	7.9	5.0
25	19.9	18.9	18.2	17.4	16.2	14.3	11.9	8.7	5.4	19.9	19.1	18.5	17.5	16.4	15.0	13.3	11.1	8.4	5.3
26	20.6	19.6	18.9	18.1	16.8	15.0	12.4	9.2	5.8	20.7	19.9	19.2	18.3	17.0	15.6	13.9	11.6	8.7	5.6
27	21.4	20.4	19.7	18.8	17.5	15.6	13.0	9.7	6.0	21.5	20.7	20.0	19.0	17.7	16.3	14.5	12.0	9.1	5.8
28	22.1	21.2	20.3	19.4	18.2	16.3	13.5	10.0	6.2	22.3	21.4	20.6	19.7	18.4	16.9	15.1	12.5	9.4	6.1
29	22.9	21.9	21.1	20.2	18.9	16.9	14.1	10.4	6.5	23.2	22.3	21.5	20.5	19.2	17.5	15.6	13.0	9.8	6.2
30	23.6	22.6	21.8	20.8	19.5	17.6	14.5	10.8	6.8	23.9	23.0	22.2	21.2	19.8	18.2	16.2	13.5	10.1	6.4
31	24.3	23.3	22.5	21.5	20.1	18.2	15.2	11.2	7.1	24.7	23.8	22.9	21.9	20.5	18.9	16.9	14.1	10.5	6.6
32	25.0	24.0	23.1	22.1	20.8	18.8	15.6	11.6	7.4	25.4	24.5	23.7	22.6	21.1	19.5	17.5	14.6	10.8	6.8
33	25.8	24.8	23.9	22.8	21.4	19.5	16.2	12.0	7.6	26.3	25.3	24.4	23.3	21.8	20.1	18.0	15.1	11.2	7.0
34	26.5	25.5	24.6	23.4	22.0	20.2	16.8	12.4	7.9	27.1	26.1	25.1	24.0	22.5	20.8	18.6	15.6	11.5	7.1
35	27.3	26.2	25.3	24.1	22.7	20.8	17.3	12.9	8.2	27.9	26.8	25.9	24.7	23.2	21.5	19.2	16.1	12.0	7.3
36	28.1	26.9	25.9	24.7	23.3	21.4	17.7	13.2	8.5	28.7	27.6	26.6	25.4	23.9	22.2	19.9	16.6	12.3	7.5
37	28.9	27.7	26.7	25.4	23.9	22.0	18.3	13.7	8.8	29.5	28.4	27.3	26.2	24.7	22.8	20.4	17.1	12.7	7.7
38	29.6	28.3	27.3	26.1	24.5	22.5	18.8	14.2	9.1	30.3	29.1	28.0	26.8	25.3	23.4	21.0	17.6	13.0	7.9

TABLE 22.—*Diameters inside bark at different heights above the ground for trees of different sizes, based on measurements of 1,548 trees in the Southern Appalachian region.*

[The heights above ground represent 16.3-foot logs and half logs plus a stump height of 2 feet.]

Diameter breast-high outside bark.	20-foot trees.	30-foot trees.	40-foot trees.		
	Height above ground—feet.				
	10.15	10.15	10.15	18.3	26.45
	Diameter inside bark—inches.				
Inches.					
2	1.1	1.3	....	....	....
3	1.9	2.1	....	....	....
4	2.6	3.0	3.2	2.6	1.6
5	3.3	3.8	4.1	3.1	2.0
6	....	4.7	4.9	3.9	2.5
7	....	5.5	5.8	4.6	3.0
8	....	6.3	6.6	5.3	3.6
9	....	7.3	7.5	6.1	4.0
10	....	8.1	8.3	6.8	4.5
11	....	....	9.2	7.6	5.0
12	....	....	10.1	8.3	5.5
13	....	....	10.9	9.1	6.0
14	....	....	11.8	9.9	6.5

Diameter breast-high outside bark.	50-foot trees.					60-foot trees.					
	Height above ground—feet.										
	10.15	18.3	26.45	34.6	42.75	10.15	18.3	26.45	34.6	42.75	50.9
	Diameter inside bark—inches.										
Inches.											
4	3.3	2.6	2.0	1.3	0.6	....	....	....	....	....	......
5	4.1	3.5	2.7	1.8	.8	....	....	....	....	....	......
6	5.0	4.2	3.3	2.2	1.0	5.1	4.4	3.8	3.0	2.1	1.0
7	5.8	5.0	4.0	2.7	1.2	5.9	5.3	4.5	3.6	2.5	1.2
8	6.6	5.8	4.6	3.1	1.4	6.8	6.1	5.2	4.2	3.0	1.5
9	7.4	6.6	5.3	3.6	1.7	7.6	6.9	6.0	4.9	3.4	1.7
10	8.4	7.4	5.9	4.0	1.9	8.5	7.7	6.7	5.5	3.9	1.9
11	9.2	8.2	6.6	4.5	2.1	9.3	8.5	7.5	6.2	4.4	2.2
12	10.1	9.0	7.2	4.9	2.3	10.1	9.4	8.3	6.9	4.9	2.4
13	10.9	9.8	8.0	5.4	2.6	11.0	10.2	9.0	7.5	5.4	2.8
14	11.8	10.6	8.6	6.0	2.9	11.9	11.1	9.8	8.2	6.0	3.0
15	12.6	11.4	9.3	6.5	3.2	12.7	11.9	10.6	8.9	6.5	3.3
16	13.6	12.3	10.0	7.0	3.5	13.6	12.7	11.4	9.6	7.0	3.6
17	14.4	13.1	10.7	7.5	3.7	14.4	13.5	12.1	10.2	7.5	3.9
18	15.3	13.9	11.4	8.0	4.0	15.3	14.4	12.9	10.9	8.0	4.2
19	16.1	14.7	12.1	8.6	4.3	16.1	15.1	13.7	11.5	8.5	4.5
20	17.0	15.5	12.8	9.1	4.7	17.0	16.0	14.4	12.2	9.0	4.8
21	....	....	....	....	....	17.8	16.7	15.2	12.9	9.5	5.1
22	....	....	....	....	....	18.7	17.6	15.9	13.5	10.0	5.4
23	....	....	....	....	....	19.6	18.3	16.7	14.2	10.5	5.7
24	....	....	....	....	....	20.4	19.1	17.4	14.8	11.0	6.1
25	....	....	....	....	....	21.3	19.9	18.1	15.4	11.4	6.3
26	....	....	....	....	....	22.1	20.6	18.8	16.0	11.9	6.7
27	....	....	....	....	....	23.0	21.4	19.5	16.6	12.4	7.0

TABLE 22.—*Diameters inside bark at different heights above the ground for trees of different sizes, based on measurements of 1,548 trees in the Southern Appalachian region*—Con.

Diameter breast-high outside bark.	70-foot trees.							80-foot trees.								
	Height above ground—feet.															
	10.15	18.3	26.45	34.6	42.75	50.9	59.05	10.15	18.3	26.45	34.6	42.75	50.9	59.05	67.2	73.35
	Diameter inside bark—inches.															
Inches.																
8	6.8	6.2	5.7	5.0	4.0	2.9	1.7	......	......	......	......	......	......	......	......	......
9	7.9	7.0	6.5	5.8	4.7	3.4	2.0	......	......	......	......	......	......	......	......	......
10	8.5	7.9	7.3	6.5	5.3	3.8	2.2	8.7	8.1	7.5	6.9	6.1	5.0	3.7	2.2	1.1
11	9.4	8.8	8.1	7.2	5.9	4.2	2.4	9.5	9.0	8.3	7.7	6.8	5.5	4.1	2.4	1.2
12	10.2	9.5	8.9	7.9	6.4	4.7	2.7	10.3	9.8	9.2	8.5	7.5	6.1	4.5	2.6	1.3
13	11.1	10.4	9.7	8.7	7.1	5.1	2.9	11.1	10.6	9.9	9.2	8.2	6.7	4.9	2.9	1.4
14	11.9	11.2	10.5	9.5	7.8	5.6	3.2	12.0	11.4	10.7	9.9	8.8	7.3	5.4	3.1	1.5
15	12.7	12.0	11.4	10.2	8.4	6.0	3.5	12.9	12.2	11.5	10.6	9.5	7.8	5.8	3.4	1.7
16	13.6	12.8	12.1	10.9	9.0	6.5	3.7	13.7	13.0	12.3	11.4	10.1	8.4	6.2	3.7	1.8
17	14.4	13.7	12.9	11.7	9.6	7.0	4.1	14.5	13.7	13.0	12.1	10.8	9.0	6.6	3.9	1.9
18	15.3	14.5	13.7	12.3	10.2	7.6	4.4	15.3	14.5	13.7	12.7	11.3	9.5	7.0	4.1	2.1
19	16.1	15.2	14.4	13.0	10.8	8.1	4.7	16.2	15.3	14.4	13.4	12.0	10.1	7.5	4.4	2.2
20	17.0	16.0	15.2	13.7	11.4	8.6	5.0	17.0	16.0	15.2	14.1	12.6	10.7	7.9	4.6	2.3
21	17.9	16.8	15.9	14.4	12.0	9.1	5.3	17.9	16.9	15.9	14.8	13.3	11.2	8.4	4.9	2.4
22	18.7	17.6	16.6	15.0	12.5	9.6	5.6	18.7	17.5	16.5	15.5	13.9	11.8	8.9	5.2	2.5
23	19.6	18.4	17.3	15.7	13.1	10.0	5.9	19.6	18.4	17.3	16.1	14.5	12.3	9.2	5.5	2.7
24	20.4	19.1	18.1	16.3	13.6	10.5	6.2	20.4	19.1	18.0	16.8	15.1	12.8	9.7	5.8	2.8
25	21.3	19.9	18.7	17.0	14.2	10.9	6.5	21.3	19.9	18.8	17.4	15.7	13.4	10.1	6.0	3.0
26	22.1	20.6	19.4	17.5	14.7	11.3	6.8	22.1	20.7	19.5	18.1	16.2	13.9	10.6	6.3	3.1
27	22.9	21.4	20.1	18.2	15.3	11.7	7.1	23.0	21.5	20.3	18.8	16.9	14.4	11.0	6.6	3.3
28	23.7	22.1	20.9	18.8	15.8	12.2	7.3	23.8	22.2	20.9	19.4	17.4	14.8	11.3	6.9	3.4
29	24.6	22.9	21.6	19.5	16.4	12.6	7.6	24.6	23.0	21.7	20.1	18.0	15.3	11.8	7.2	3.6
30	25.4	23.7	22.3	20.1	16.9	12.9	7.9	25.5	23.8	22.4	20.8	18.7	15.9	12.2	7.5	3.8
31	26.2	24.5	23.0	20.8	17.5	13.3	8.2	26.3	24.6	23.1	21.4	19.2	16.3	12.5	7.7	4.0
32	27.0	25.2	23.7	21.4	18.0	13.7	8.5	27.1	25.3	23.7	22.0	19.7	16.7	12.8	8.0	4.1
33	......	......	......	......	......	......	......	28.0	26.1	24.4	22.6	20.3	17.1	13.1	8.2	4.2
34	......	......	......	......	......	......	......	28.8	26.8	25.2	23.4	20.8	17.5	13.4	8.4	4.4
35	......	......	......	......	......	......	......	29.7	27.6	25.9	24.0	21.4	18.0	13.9	8.7	4.5

Diameter breast-high outside bark.	90-foot trees.										
	Height above ground—feet.										
	10.15	18.3	26.45	34.6	42.75	50.9	59.05	67.2	75.35	83.5	91.65
	Diameter inside bark—inches.										
Inches.											
10	8.7	8.3	7.8	7.3	6.8	6.0	4.8	3.4	2.1	0.9	......
11	9.5	9.1	8.6	8.0	7.4	6.6	5.4	3.9	2.4	1.0	......
12	10.3	9.9	9.4	8.8	8.1	7.2	5.9	4.3	2.6	1.2	......
13	11.2	10.7	10.2	9.5	8.8	7.9	6.5	4.7	2.9	1.2	......
14	12.0	11.5	10.9	10.2	9.4	8.5	7.0	5.0	3.1	1 3.	......
15	12.9	12.3	11.6	10.9	10.1	9.1	7.5	5.4	3.3	1.4	......
16	13.7	13.1	12.4	11.6	10.7	9.7	8.0	5.8	3.6	1.5	......
17	14.5	13.9	13.1	12.3	11.4	10.2	8.4	6.2	3.8	1.6	......
18	15.4	14.6	13.8	13.0	12.1	10.8	8.9	6.6	4.1	1.7	......
19	16.2	15.3	14.5	13.7	12.7	11.4	9.4	6.9	4.3	1.9	......
20	17.1	16.1	15.2	14.4	13.4	12.0	9.9	7.3	4.6	2.0	......
21	17.9	16.8	16.0	15.2	14.1	12.6	10.4	7.7	4.9	2.1	......
22	18.8	17.6	16.7	15.8	14.7	13.1	10.9	8.1	5.1	2.2	......
23	19.6	18.4	17.4	16.5	15.3	13.7	11.4	8.5	5.4	2.3	......
24	20.5	19.2	18.2	17.2	16.0	14.2	11.9	8.9	5.6	2.4	......
25	21.3	20.0	18.9	17.9	16.6	14.8	12.4	9.4	5.9	2.5	......

TABLE 22.—*Diameters inside bark at different heights above the ground for trees of different sizes, based on measurements of 1,548 trees in the Southern Appalachian region*—Con.

Diameter breast-high outside bark.	90-foot trees.										
	Height above ground—feet.										
	10.15	18.3	26.45	34.6	42.75	50.9	59.05	67.2	75.35	83.5	91.65
	Diameter inside bark—inches.										
Inches.											
26	22.2	20.7	19.7	18.6	17.2	15.3	12.9	9.8	6.1	2.6	......
27	23.0	21.5	20.4	19.3	17.9	16.0	13.4	10.2	6.5	2.8	......
28	23.8	22.3	21.1	19.9	18.4	16.5	13.9	10.6	6.7	2.9	......
29	24.7	23.1	21.9	20.6	19.1	17.1	14.4	11.0	7.1	3.1	......
30	25.5	23.8	22.6	21.3	19.7	17.6	14.9	11.4	7.3	3.2	......
31	26.3	24.6	23.3	22.0	20.3	18.2	15.4	11.8	7.6	3.4	......
32	27.2	25.4	24.0	22.6	20.9	18.6	15.8	12.2	7.8	3.5	......
33	28.0	26.2	24.8	23.3	21.5	19.2	16.4	12.6	8.1	3.6	......
34	28.8	27.0	25.5	24.0	22.1	19.7	16.8	13.0	8.4	3.7	......
35	29.6	27.7	26.2	24.6	22.7	20.2	17.3	13.4	8.6	3.8	......
36	30.5	28.6	26.9	25.4	23.3	20.7	17.8	13.7	8.8	3.9	......
37	31.3	29.3	27.7	26.1	23.9	21.2	18.3	14.2	9.2	4.0	......
38	32.2	30.1	28.4	26.8	24.6	21.7	18.7	14.6	9.4	4.1	......
39	33.0	30.8	29.1	27.4	25.2	22.2	19.2	15.0	9.7	4.2	......
40	33.8	31.6	29.8	28.1	25.7	22.7	19.6	15.3	9.9	4.3	......
41	34.6	32.4	30.6	28.7	26.4	23.3	20.1	15.7	10.3	4.6	......
42	35.4	33.2	31.3	29.3	26.9	23.8	20.5	16.2	10.8	4.8	......
43	36.2	34.0	32.1	30.0	27.6	24.4	20.9	16.6	11.1	5.0	......
	100-foot trees.										
12	10.3	9.9	9.4	8.9	8.3	7.6	6.7	5.4	4.0	2.6	1.3
13	11.2	10.7	10.1	9.6	9.0	8.3	7.2	5.9	4.4	2.9	1.5
14	12.0	11.5	10.9	10.3	9.7	8.9	7.7	6.3	4.7	3.1	1.6
15	12.9	12.3	11.6	11.0	10.4	9.7	8.3	6.8	5.2	3.4	1.8
16	13.8	13.0	12.4	11.8	11.1	10.1	8.9	7.3	5.6	3.8	2.0
17	14.6	13.8	13.1	12.4	11.8	10.8	9.5	7.9	6.0	4.0	2.1
18	15.5	14.6	13.8	13.1	12.3	11.4	10.1	8.4	6.4	4.3	2.2
19	16.2	15.3	14.5	13.8	13.0	12.0	10.7	8.9	6.8	4.6	2.3
20	17.1	16.1	15.3	14.5	13.6	12.6	11.3	9.3	7.2	4.8	2.4
21	18.0	16.9	16.0	15.2	14.4	13.3	11.8	9.9	7.6	5.1	2.5
22	18.8	17.7	16.8	16.0	15.0	13.9	12.3	10.3	8.0	5.3	2.6
23	19.7	18.5	17.5	16.6	15.7	14.6	12.9	10.8	8.3	5.6	2.8
24	20.5	19.2	18.3	17.4	16.4	15.1	13.5	11.3	8.7	5.7	2.9
25	21.4	20.0	18.9	18.1	17.1	15.8	14.0	11.8	9.0	6.0	3.0
26	22.2	20.8	19.7	18.7	17.7	16.3	14.6	12.3	9.4	6.2	3.1
27	23.1	21.6	20.5	19.6	18.5	17.0	15.2	12.8	9.8	6.5	3.2
28	23.9	22.3	21.3	20.2	19.1	17.6	15.8	13.3	10.1	6.7	3.3
29	24.7	23.2	22.1	21.1	19.9	18.3	16.4	13.8	10.5	6.9	3.5
30	25.5	24.0	22.9	21.8	20.5	18.8	16.9	14.3	10.8	7.1	3.6
31	26.4	24.7	23.6	22.6	21.2	19.4	17.5	14.8	11.2	7.4	3.7
32	27.2	25.5	24.4	23.3	21.9	20.1	18.1	15.2	11.5	7.6	3.8
33	28.1	26.3	25.2	24.1	22.6	20.7	18.7	15.8	12.0	7.9	4.0
34	28.8	27.0	25.9	24.8	23.2	21.3	19.2	16.3	12.3	8.0	4.1
35	29.7	27.8	26.7	25.5	23.9	22.0	19.8	16.8	12.7	8.3	4.3
36	30.5	28.6	27.4	26.2	24.6	22.6	20.3	17.2	13.1	8.6	4.4
37	31.4	29.4	28.2	26.9	25.3	23.2	20.9	17.7	13.4	8.8	4.5
38	32.2	30.1	28.9	27.6	25.9	23.8	21.4	18.1	13.7	9.1	4.6
39	33.1	30.9	29.6	28.3	26.6	24.5	22.0	18.6	14.1	9.3	4.9
40	33.8	31.7	30.3	29.0	27.3	25.1	22.6	19.1	14.4	9.5	5.0
41	34.7	32.4	31.1	29.8	28.1	25.8	23.1	19.6	14.8	9.7	5.1
42	35.5	33.3	31.8	30.5	28.8	26.4	23.7	20.1	15.1	9.9	5.2
43	36.3	34.0	32.5	31.2	29.5	27.1	24.3	20.6	15.5	10.3	5.4
44	37.1	34.8	33.2	31.9	30.2	27.7	24.9	21.1	15.9	10.5	5.5
45	37.9	35.5	34.0	32.6	30.9	28.4	25.5	21.5	16.3	10.9	5.7

TABLE 22.—*Diameters inside bark at different heights above the ground for trees of different sizes, based on measurements of 1,548 trees in the Southern Appalachian region*—Con.

Diameter breast-high outside bark.	110-foot trees.												
	Height above ground—feet.												
	10.15	18.3	26.45	34.6	42.75	50.9	59.05	67.2	75.35	83.5	91.65	99.8	107.95
	Diameter inside bark—inches.												
Inches.													
15	13.0	12.4	11.7	11.2	10.8	10.1	9.3	8.1	6.6	4.8	3.1	1.7	......
16	13.8	13.0	12.4	11.9	11.4	10.7	9.9	8.6	7.0	5.2	3.3	1.7	......
17	14.7	13.8	13.2	12.7	12.1	11.3	10.5	9.2	7.5	5.5	3.5	1.9	......
18	15.5	14.6	13.9	13.3	12.7	12.0	11.0	9.7	8.0	5.9	3.7	1.9	......
19	16.3	15.3	14.6	14.0	13.4	12.7	11.6	10.3	8.5	6.3	3.9	2.0	......
20	17.1	16.1	15.4	14.7	14.0	13.3	12.2	10.8	9.0	6.7	4.1	2.1	......
21	18.0	16.9	16.1	15.5	14.7	13.9	12.8	11.3	9.5	7.1	4.4	2.2	.....
22	18.8	17.6	16.9	16.2	15.3	14.5	13.4	11.9	10.0	7.4	4.6	2.4	......
23	19.6	18.4	17.7	17.0	16.1	15.2	13.9	12.4	10.5	7.8	4.9	2.5	......
24	20.5	19.2	18.4	17.6	16.7	15.8	14.6	13.0	11.0	8.3	5.2	2.6	......
25	21.3	20.1	19.2	18.4	17.5	16.5	15.2	13.5	11.5	8.7	5.5	2.8	......
26	22.2	20.8	19.9	19.1	18.1	17.1	15.8	14.1	12.0	9.1	5.8	2.9	......
27	23.1	21.7	20.7	19.9	18.9	17.8	16.4	14.7	12.5	9.5	6.1	3.1	......
28	23.9	22.5	21.4	20.5	19.6	18.5	17.0	15.3	12.9	9.8	6.4	3.2	......
29	24.8	23.3	22.2	21.3	20.4	19.2	17.7	15.9	13.4	10.1	6.7	3.4	......
30	25.6	24.1	22.9	22.1	21.1	19.8	18.3	16.4	13.8	10.5	6.9	3.5	......
31	26.5	24.9	23.8	22.8	21.9	20.6	19.0	17.0	14.3	10.9	7.2	3.7	......
32	27.3	25.7	24.5	23.5	22.5	21.2	19.6	17.5	14.7	11.3	7.5	3.9	......
33	28.1	26.4	25.3	24.3	23.3	21.9	20.3	18.1	15.3	11.8	7.8	4.1	......
34	29.0	27.2	26.0	25.1	24.0	22.7	20.9	18.6	15.7	12.2	8.1	4.2	......
35	29.9	28.0	26.9	25.9	24.8	23.4	21.6	19.2	16.3	12.6	8.4	4.5	......
36	30.7	28.7	27.6	26.6	25.5	24.1	22.2	19.7	16.7	13.0	8.7	4.6	......
37	31.5	29.5	28.4	27.4	26.3	24.9	22.9	20.3	17.2	13.3	9.0	4.8	......
38	32.3	30.3	29.2	28.2	26.9	25.5	23.5	20.9	17.6	13.7	9.3	5.0	......
39	33.1	31.1	30.0	29.0	27.7	26.2	24.2	21.5	18.1	14.0	9.7	5.3	......
40	33.9	31.9	30.7	29.7	28.5	26.9	24.8	22.1	18.6	14.4	10.1	5.5	......
41	34.7	32.7	31.5	30.4	29.2	27.6	25.5	22.7	19.1	15.0	10.3	5.7	......
42	35.6	33.5	32.3	31.2	29.9	28.3	26.1	23.2	19.6	15.3	10.6	6.0	......
43	36.4	34.2	33.0	32.0	30.6	29.0	26.8	23.9	20.1	15.7	11.0	6.2	......
44	37.3	35.0	33.8	32.7	31.4	29.7	27.4	24.4	20.6	16.1	11.3	6.4	......
45	38.1	35.8	34.6	33.5	32.1	30.4	28.1	25.1	21.1	16.5	11.7	6.8	......
	120-foot trees.												
16	14.0	13.1	12.4	11.7	11.1	10.5	9.8	9.0	7.8	6.2	4.4	2.6	1.6
17	14.8	13.9	13.2	12.5	11.9	11.2	10.4	9.6	8.4	6.7	4.8	2.9	1.3
18	15.6	14.7	13.9	13.2	12.6	12.0	11.0	10.2	8.9	7.1	5.2	3.2	1.5
19	16.4	15.5	14.7	13.9	13.3	12.6	11.7	10.8	9.5	7.7	5.6	3.6	1.9
20	17.3	16.3	15.5	14.7	14.0	13.3	12.4	11.4	10.0	8.1	5.9	3.7	2.0
21	18.0	16.9	16.3	15.4	14.7	14.0	13.1	12.0	10.6	8.6	6.3	4.0	2.2
22	18.9	17.7	17.0	16.2	15.4	14.8	13.8	12.6	11.2	9.1	6.6	4.3	2.5
23	19.6	18.5	17.8	16.9	16.2	15.5	14.4	13.3	11.7	9.6	7.0	4.6	2.6
24	20.5	19.3	18.6	17.7	16.9	16.2	15.1	13.9	12.3	10.0	7.4	4.9	2.8
25	21.3	20.1	19.3	18.5	17.7	16.9	15.8	14.5	12.9	10.6	7.9	5.2	3.0
26	22.1	20.9	20.1	19.3	18.4	17.6	16.5	15.2	13.5	11.1	8.3	5.5	3.2
27	22.9	21.7	20.9	20.1	19.3	18.4	17.2	15.8	14.0	11.6	8.8	5.8	3.4
28	23.8	22.5	21.6	20.9	20.1	19.1	17.9	16.5	14.6	12.1	9.2	6.1	3.6
29	24.6	23.2	22.4	21.6	20.9	19.9	18.5	17.1	15.2	12.6	9.6	6.5	3.9
30	25.5	24.1	23.2	22.5	21.7	20.6	19.2	17.7	15.8	13.2	10.0	6.8	4.0
31	26.4	24.8	24.0	23.3	22.5	21.4	19.9	18.4	16.4	13.7	10.5	7.1	4.3
32	27.3	25.7	24.8	24.1	23.3	22.1	20.8	19.1	17.0	14.2	11.0	7.5	4.4
33	28.1	26.5	25.6	24.9	24.0	22.9	21.5	19.7	17.5	14.7	11.4	7.8	4.7
34	29.0	27.3	26.4	25.6	24.8	23.6	22.3	20.4	18.1	15.3	11.9	8.2	4.9
35	29.8	28.1	27.1	26.4	25.6	24.4	22.9	21.0	18.7	15.8	12.4	8.5	5.1
36	30.7	28.9	27.9	27.1	26.3	25.1	23.6	21.6	19.3	16.3	12.8	8.9	5.3
37	31.6	29.6	28.7	27.9	27.1	25.9	24.3	22.3	19.9	16.9	13.2	9.3	5.6
38	32.4	30.5	29.4	28.6	27.8	26.6	24.9	22.9	20.5	17.4	13.6	9.6	5.8
39	33.3	31.2	30.2	29.4	28.6	27.3	25.7	23.6	21.0	17.9	14.1	10.0	6.1
40	34.1	32.0	31.0	30.2	29.3	28.0	26.4	24.2	21.6	18.4	14.6	10.3	6.3
41	34.9	32.8	31.7	31.0	30.1	28.8	27.1	24.9	22.2	18.8	15.0	10.7	6.6
42	35.8	33.6	32.5	31.7	30.8	29.5	27.7	25.5	22.8	19.3	15.4	11.1	6.8
43	36.6	34.4	33.3	32.5	31.5	30.2	28.5	26.1	23.3	19.8	15.9	11.6	7.1
44	37.5	35.2	34.1	33.3	32.3	31.0	29.2	26.8	23.9	20.3	16.3	11.8	7.3
45	38.2	35.9	34.8	34.0	33.0	31.6	29.9	27.4	24.4	20.8	16.8	12.2	7.6
46	39.1	36.8	35.7	34.7	33.7	32.3	30.6	28.1	25.0	21.3	17.1	12.5	7.8
47	40.0	37.6	36.4	35.5	34.5	33.1	31.3	28.8	25.6	21.8	17.6	12.9	8.0

TABLE 22.—*Diameters inside bark at different heights above the ground for trees of different sizes, based on measurements of 1,548 trees in the Southern Appalachian region*—Con.

Diameter breast-high outside bark.	130-foot trees.														
	Height above ground—feet.														
	10.15	18.3	26.45	34.6	42.75	50.9	59.05	67.2	75.35	83.5	91.65	99.8	107.95	116.1	124.25
	Diameter inside bark—inches.														
Inches.															
18......	15.4	14.5	13.8	13.1	12.4	11.7	10.9	9.9	8.7	7.4	6.0	4.6	3.3	2.0	......
19......	16.4	15.3	14.6	13.9	13.2	12.5	11.7	10.6	9.3	8.0	6.5	5.0	3.6	2.2	......
20......	17.3	16.1	15.4	14.7	14.0	13.3	12.5	11.3	9.9	8.6	7.1	5.5	3.9	2.4	......
21......	18.2	17.0	16.2	15.5	14.8	14.1	13.3	12.1	10.7	9.2	7.6	6.0	4.2	2.6	......
22......	18.9	17.7	17.0	16.3	15.6	14.8	14.1	12.8	11.4	9.8	8.1	6.3	4.5	2.8	......
23......	19.9	18.5	17.8	17.1	16.4	15.6	14.8	13.6	12.1	10.4	8.6	6.7	4.8	3.0	......
24......	20.7	19.3	18.6	17.9	17.2	16.4	15.5	14.3	12.7	11.0	9.1	7.1	5.1	3.2	......
25......	21.6	20.2	19.5	18.7	18.0	17.2	16.4	15.0	13.5	11.7	9.7	7.5	5.4	3.4	......
26......	22.3	21.0	20.2	19.5	18.8	18.0	17.1	15.7	14.1	12.4	10.2	7.9	5.7	3.6	......
27......	23.2	21.8	21.1	20.4	19.7	18.9	17.9	16.5	14.9	13.0	10.8	8.4	6.0	3.8	......
28......	24.0	22.7	21.8	21.1	20.4	19.6	18.6	17.2	15.5	13.6	11.2	8.7	6.3	4.1	......
29......	24.8	23.4	22.7	22.0	21.3	20.5	19.4	17.9	16.2	14.2	11.8	9.2	6.6	4.2	......
30......	25.6	24.2	23.4	22.8	22.1	21.2	20.1	18.6	16.9	14.8	12.3	9.6	6.9	4.4	......
31......	26.5	25.0	24.3	23.7	22.9	22.0	20.9	19.4	17.6	15.5	12.9	10.0	7.3	4.6	......
32......	27.3	25.8	25.0	24.4	23.7	22.8	21.6	20.1	18.3	16.1	13.4	10.4	7.6	4.9	......
33......	28.2	26.6	26.0	25.2	24.5	23.6	22.3	20.8	19.1	16.8	13.9	10.9	8.0	5.1	......
34......	29.0	27.4	26.7	26.0	25.3	24.4	23.1	21.6	19.7	17.4	14.5	11.3	8.3	5.3	......
35......	30.0	28.2	27.5	26.8	26.1	25.2	23.9	22.4	20.5	18.0	15.1	11.8	8.7	5.6	......
36......	30.8	28.9	28.2	27.5	26.8	25.9	24.7	23.1	21.1	18.6	15.6	12.2	9.0	5.8	......
37......	31.7	29.7	29.1	28.4	27.6	26.7	25.4	23.8	21.8	19.2	16.1	12.7	9.4	6.0	......
38......	32.5	30.5	29.9	29.1	28.3	27.4	26.2	24.5	22.4	19.7	16.6	13.1	9.7	6.3	......
39......	33.4	31.3	30.7	29.9	29.1	28.2	27.0	25.2	23.1	20.4	17.1	13.6	10.0	6.4	......
40......	34.2	32.1	31.4	30.7	29.8	28.9	27.7	25.9	23.7	20.9	17.5	13.9	10.3	6.6	......
41......	35.1	32.9	32.2	31.5	30.6	29.6	28.4	26.6	24.5	21.7	18.1	14.4	10.7	6.9	......
42......	35.9	33.7	33.0	32.2	31.3	30.4	29.1	27.2	25.1	22.2	18.5	14.8	11.0	7.1	......
43......	36.8	34.6	33.7	33.0	32.1	31.0	29.8	28.1	25.8	22.8	19.0	15.2	11.4	7.3	......
44......	37.6	35.3	34.5	33.7	32.8	31.8	30.5	28.7	26.4	23.2	19.4	15.6	11.7	7.6	......
45......	38.6	36.3	35.3	34.5	33.5	32.5	31.2	29.4	27.0	23.9	20.0	16.1	12.1	7.8	......
46......	39.3	37.0	36.1	35.3	34.4	33.2	31.8	30.0	27.7	24.4	20.4	16.4	12.3	7.9	......
47......	40.3	37.9	36.8	36.1	35.1	34.0	32.6	30.7	28.4	25.1	20.9	16.8	12.6	8.1	......
	140-foot trees.														
24......	20.6	19.4	18.8	18.4	17.7	16.8	15.7	14.6	13.4	12.2	10.7	9.1	7.4	5.6	3.6
25......	21.5	20.2	19.6	19.2	18.5	17.6	16.4	15.3	14.1	12.8	11.3	9.6	7.7	5.8	3.7
26......	22.3	21.1	20.5	20.0	19.3	18.3	17.2	16.0	14.8	13.5	11.9	10.1	8.1	6.0	3.9
27......	23.1	21.8	21.3	20.7	20.0	19.1	18.0	16.8	15.5	14.1	12.5	10.5	8.4	6.3	4.1
28......	24.0	22.6	21.9	21.4	20.7	19.8	18.8	17.5	16.2	14.7	13.0	11.0	8.8	6.5	4.2
29......	24.8	23.4	22.8	22.3	21.5	20.6	19.6	18.4	17.0	15.4	13.6	11.4	9.2	6.8	4.5
30......	25.7	24.3	23.5	23.0	22.3	21.4	20.3	19.1	17.8	16.0	14.1	12.0	9.5	7.1	4.7
31......	26.5	25.1	24.4	23.8	23.1	22.3	21.2	19.9	18.4	16.7	14.7	12.4	9.9	7.4	4.8
32......	27.4	25.9	25.2	24.6	23.9	23.1	22.0	20.6	19.1	17.3	15.3	12.9	10.3	7.6	5.0
33......	28.2	26.7	26.0	25.4	24.6	23.9	22.8	21.4	19.8	17.9	15.8	13.4	10.7	7.9	5.1
34......	29.1	27.6	26.8	26.2	25.5	24.6	23.5	22.2	20.6	18.6	16.4	13.9	11.1	8.2	5.3
35......	29.9	28.3	27.5	26.8	26.1	25.4	24.3	22.9	21.3	19.3	17.0	14.4	11.4	8.5	5.5
36......	30.8	29.2	28.3	27.6	26.9	26.1	25.0	23.6	22.0	19.9	17.5	14.8	11.8	8.7	5.7
37......	31.6	30.0	29.1	28.4	27.7	26.9	25.7	24.3	22.6	20.5	18.1	15.3	12.2	9.1	5.9
38......	32.5	30.9	29.9	29.2	28.5	27.6	26.5	25.1	23.4	21.2	18.7	15.8	12.6	9.4	6.1
39......	33.4	31.6	30.7	29.9	29.2	28.3	27.3	26.0	24.2	21.9	19.3	16.3	13.0	9.7	6.3
40......	34.3	32.5	31.5	30.7	29.9	29.0	28.0	26.7	25.0	22.6	19.8	16.7	13.3	10.0	6.5
41......	35.2	33.3	32.3	31.5	30.7	29.9	28.7	27.4	25.7	23.3	20.4	17.1	13.7	10.3	6.7
42......	36.1	34.1	33.0	32.3	31.5	30.6	29.5	28.1	26.5	24.0	20.9	17.6	14.1	10.7	7.0
43......	37.0	34.9	33.9	33.1	32.3	31.4	30.2	28.9	27.1	24.7	21.6	18.1	14.5	11.0	7.2
44......	37.9	35.7	34.6	33.8	33.1	32.1	31.0	29.6	27.9	25.3	22.1	18.5	14.9	11.3	7.5
45......	38.8	36.5	35.4	34.6	33.8	32.9	31.8	30.4	28.6	26.0	22.7	19.0	15.3	11.7	7.7
46......	39.7	37.4	36.2	35.4	34.6	33.6	32.4	31.1	29.4	26.7	23.2	19.5	15.6	12.0	7.9
47......	40.5	38.2	37.1	36.2	35.2	34.3	33.2	31.9	30.1	27.4	23.8	19.9	16.0	12.2	8.1
48......	41.5	39.1	37.8	37.0	36.0	35.0	34.0	32.8	31.0	28.0	24.3	20.3	16.4	12.5	8.3
49......	42.3	39.9	38.8	37.8	36.8	35.9	34.8	33.5	31.6	28.7	24.9	20.9	16.8	12.8	8.5
50......	43.3	40.8	39.5	38.6	37.6	36.5	35.5	34.2	32.4	29.3	25.5	21.3	17.1	13.1	8.7

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BULLETIN OF THE U.S. DEPARTMENT OF AGRICULTURE

No. 153

Contribution from the Forest Service, Henry S. Graves, Forester.

January 28, 1915.

FOREST PLANTING IN THE EASTERN UNITED STATES.

By C. R. TILLOTSON, *Forest Examiner.*

OPPORTUNITIES FOR FOREST PLANTING.

Nearly every farm includes one or more pieces of land which can be more profitably planted to timber than to an agricultural crop. Such an area may be some small corner not easily accessible, or else a piece of poor, sandy, swampy, or worn-out land, or it may be an old woodlot in poor condition and not fully stocked with growing timber.

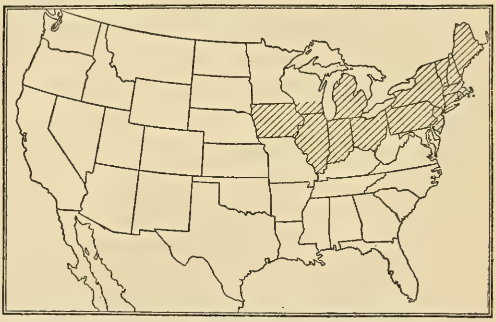

FIG. 1.—Sketch map of the United States, the shaded area showing section studied in this bulletin.

The 1910 census shows that the average farm in the United States contains 138 acres, of which 75 are recorded as improved and 63 as unimproved, the latter consisting of "woodland" and "all other unimproved land."[1] The woodland and other unimproved land covers the enormous total area of 400,346,000 acres. Of this nearly 245,000,000 acres are in the States east of Texas and the Rocky Mountains, about 175,000,000 acres of which are in woodlots. There remain about 70,000,000 acres of unforested and unimproved land in this eastern portion of the country, most of it best suited for growing timber. This area will be reduced by draining the swamp lands potentially adapted to agricultural crops, but will be increased by the addition of lands becoming worn out and unfit for growing field crops.

Since 1870 in New England the proportion of improved farm land has gradually declined as follows: In 1870, 61.3 per cent; in 1880,

[1] "Woodland" includes all land covered with natural or planted forest trees which produce, or later may produce, firewood or other forest products. "All other unimproved lands" includes brush land, rough or stony land, swampy land, and any other not improved or in forest.

NOTE.—This bulletin is of interest to landowners throughout the northeastern United States, as shown by the shaded portion of the sketch map on this page.

61.2 per cent; in 1890, 54.4 per cent; in 1900, 39.6 per cent; in 1910, 36.8 per cent. These figures indicate a tendency to discontinue the use of land for purposes for which it is unfitted. Most of the unimproved farm land in the East and the Middle West is best suited to the growing of timber. Conditions in this region, moreover, are particularly favorable for fire protection, intensive management, and a maximum yield.

Timber brings the highest price, of course, where the natural supply is becoming scarce. In 1900 the average value of sawlogs in the United States was $6.28 per thousand feet, board measure; in Iowa, Indiana, and Ohio it was $12.16, $9.39, and $9.47, respectively. The higher prices in these States were due partly to local scarcity and partly to the fact that the timber consisted almost entirely of the more valuable hardwoods.

Lumber is manufactured usually in the locality of the standing timber. Wood-manufacturing plants in some States formerly rich in certain kinds of timber are now compelled to obtain their raw material from neighboring States. At one time four-fifths of the area of Indiana was covered with forests of valuable hardwoods. In 1900, 82 per cent of the lumber manufactured in that State came from outside.

The price of fence posts of the more valuable species has doubled in some places during the last 20 years. To what extent the price will continue to advance is difficult to say, because of the introduction of preservative treatments for the poorer, cheaper kinds of timbers, making them fully as useful as the higher grade timbers untreated, and also because of the increasing use of concrete posts. Wooden posts will always be needed for temporary fences, however, and many farmers will undoubtedly always prefer them for permanent ones because of their light weight. A farm of 160 acres requires annually 75 to 100 posts for the repair of fences and often additional ones for temporary fences. A small plantation of trees suitable for fence posts appears, then, to be a very desirable farm asset.

Another class of forest products for a timber plantation is that of cordwood for domestic use and for sale. The annual consumption of cordwood in the United States to-day is about 86,000,000 cords.[1] In large cities—those of 30,000 inhabitants or more—at the present day, the average value of firewood is about $7 per cord, and in cities of 1,000 to 30,000 population this value averages about $4 per cord.

A number of the States, through demonstration areas and the distribution of stock free of charge or at cost, are taking active steps to encourage forest planting. Sixteen States [2] have sought further

[1] Forest Service Circular 181.

[2] Alabama, Connecticut, Illinois, Iowa, Kansas, Massachusetts, Maine, Minnesota, Nebraska, New Hampshire, North Dakota, Rhode Island, Vermont, Washington, Wisconsin, Wyoming.

to induce planting by systems of tax exemptions, bounties, or prizes. Such provisions, however, have not always been carefully drawn. In some cases the application of the law has been restricted to a certain list of trees from which valuable species well adapted to planting have been omitted; the number of trees per acre specified for planting and the regulations regarding thinnings have not always been drawn in accordance with scientific principles of forestry; the period of exemption, or bounties, has sometimes been too short, applying only when the trees are small and the taxes on them normally light. Assessors, moreover, have sometimes adopted the practice of adding enough to the assessment of some other property of the timber owner to make up for the reduction on his plantation. Laws of this kind, however, even though they may have shown little in the way of results, indicate a willingness on the part of the various States to encourage forest planting.

STATUS OF FOREST PLANTING IN THE REGION.

PRAIRIE REGION.

The settlers in the prairie region came from wooded countries and knew the value of trees for protective purposes. In consequence, they planted timber trees primarily for protection against the cold winds of winter and the hot, drying winds of summer. Wood production was a secondary consideration. By 1885 Kansas had 147,340 acres of forest plantation, and Iowa, at about the same time, had 100,000 acres. From 50 to 75 per cent of the trees set out were the hardy, rapid-growing cottonwood, silver maple, and willow. Among the other species represented were green ash, black walnut, butternut, balsam fir, European larch, Norway spruce, white spruce, black cherry, arborvitæ, red cedar, Scotch pine, white pine, black locust, osage orange, honey locust, and hardy catalpa. In one portion or another of the prairie region each of these species has found conditions favorable for growth.

However, the hardwoods that were most generally planted are not so good for windbreak purposes as are the conifers, which retain their foliage through the winter. Because of this fact, and also because many of the older plantations are maturing, the latter are now being removed. Much of the land they have occupied is worth from $100 to $150 or more per acre when put in agricultural crops. For this reason forest planting is no longer being carried on to anything like the extent it once was, though extravagant claims made for hardy catalpa by certain tree agents have resulted in a considerable quantity of this species being set out recently for post and pole production.

As the old plantations are cut and the need is felt for new windbreaks to take their place, trees will be planted for this purpose. White pine, Norway spruce, and white spruce are likely to be the favorite species. There will be some planting to provide shade for stock and to grow fence posts and other products for use on the farm. Such plantations, however, will be restricted to the less valuable land, and their extent will depend very largely on the success of those already established.

In some of the more newly settled districts, as yet practically treeless, planting of the rapid-growing hardwoods is still going on, and will probably continue for some time.

CENTRAL HARDWOOD REGION.

The central hardwood region comprises Ohio, Indiana, Kentucky, and southern Michigan. Thus far very little planting has been done in any of these States. When the settlers in Iowa, Nebraska, and Kansas were setting out trees, the men of the central region were engaged in clearing their land of one of the finest hardwood forests in the world, which stood as a barrier against agricultural development.

Within the past 5 or 10 years, however, forest planting has received a stimulus through the activities of State forest officers, and also through the distribution by some of the States, either free or at cost, of forest-tree seedlings raised in State nurseries. By 1910 Ohio had distributed more than 1,000,000 of such seedlings, and in 1907 and 1908 Michigan distributed 396,000. Indiana and Michigan have State demonstration areas where different species are planted experimentally.

As the soil in portions of the hardwood regions deteriorates under cultivation, larger and larger areas will find their best use in the production of timber. In Indiana alone some 6,000,000 acres are at present unproductive. The chief purpose of planting will probably be to secure fence posts, handle material, and other products which can be grown in a comparatively short time. At present the species most widely planted are black locust and hardy catalpa. Others being set out include white ash, white, Scotch, and western yellow pine, yellow poplar, various oaks, European larch, Norway spruce, chestnut, and black walnut.

NORTHEAST REGION.

Early conditions in the northeast region, comprising Pennsylvania, New Jersey, New York, and the New England States, were much the same as in the central hardwood region. There was an abundance of natural timber which was gradually removed with the development of agriculture. Yet the first experiments in forest planting in

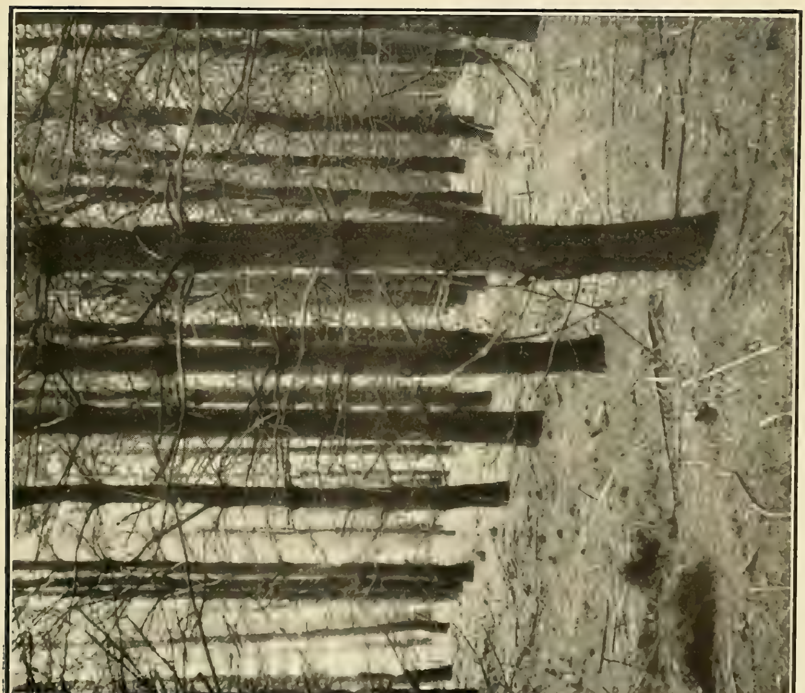

FIG. 1.—WHITE PINE PLANTATION, CENTRAL IOWA, 37 YEARS OLD, SPACED 8 BY 9 FEET. WHITE PINE GROWS WELL HERE.

FIG. 2.—MIXED PLANTATION OF OAK, ASH, ELM, AND MAPLE, INDIANA, 15 YEARS OLD, USED AS A WINDBREAK.

the United States were made in New England. One of the earliest plantations of which there is record was set out in 1819 near Chelmsford, Mass., when the Rev. J. L. Russell transplanted a large number of pitch-pine seedlings from a field he wished to cultivate to a stretch of barren drift sand. In 20 years he had a fine stand of pine from 6 to 8 inches in diameter. In 1820 Zacharias Allen planted about 40 acres of waste land at Smithfield, R. I., with oak, hickory, and locust. A careful account of all expenditures and receipts was kept, and at the end of 57 years the books showed a profit of 6.92 per cent on the capital invested.

Present-day conditions in New England well illustrate the principle that in older communities the size of the farm reflects the potential value of the soil for agricultural crops. The poorer the soil the larger will be the individual farm and the less intensive the cultivation. Thus in the period between 1850 and 1910 the size of the average farm in Maine increased from 97.2 to 104.9 acres; in Vermont, from 138.6 to 142.6 acres; and in New Hampshire, from 116 to 120.1 acres; while during the same period the average farm in Ohio decreased from 125 to 88.6 acres; in Indiana, from 136.2 to 98.8 acres; and in Illinois, from 158 to 129.1 acres.

In the States with the poorer soils, as indicated by the increasing size of the average farm, forest planting by private owners may be expected to increase. Of the approximately 10,000,000 acres of abandoned farm lands, 1,000,000 acres are in New Hampshire, and large areas lie within the other New England States. On most of these lands natural reforestation is slow, except in the case of inferior species, such as gray birch. White pine is the tree being planted most in New England. Though admirably adapted to the region, it is subject to serious damage by the white pine weevil (*Pissodes strobi*), and for this reason some other species, possibly Norway pine, may to some extent take its place in future planting. The eastern region is adapted to the growth of any of the northern hardwoods or conifers, and the choice of species will depend largely upon the relative rate of growth and the value of the products which it is possible to obtain. Massachusetts, Vermont, New Hampshire, Connecticut, and New York all distribute tree seedlings. In 1910 the demand by private owners in New York for State-grown white pine transplants amounted to nine times the supply available for distribution. Massachusetts, Connecticut, and New York also maintain State demonstration areas. Because of the relatively large proportion of wornout land the eastern region offers exceptional opportunities for forest planting. As a matter of fact, forest planting as a commercial enterprise is being more widely agitated in New England to-day than anywhere else in the United States.

ESTABLISHMENT OF PLANTATIONS.

NURSERY STOCK.

In choosing planting stock the planting site and the probable care of the growing seedlings must be taken into account. With hardwood trees, such as ash, maple, locust, or catalpa, 1-year-old stock is suitable. It costs less, is cheaper to plant, and is just as likely to thrive as older stock.

With coniferous trees, such as pine or spruce, 2-year-old seedlings or transplants or 3-year-old transplants are best. Transplant stock of conifers, when 2 or 3 years old, has a more fibrous and better developed root system than corresponding seedling stock, and is more likely to succeed than the latter, especially under unfavorable conditions. Transplant stock should always be used on heavy soils where for any reason cultivation is impossible and the young trees must compete with a heavy growth of grass. This would apply, for example, to cut-over areas filled with roots of old trees and to very steep slopes.

Tree seedlings, especially of hardwoods, can be raised on a farm at low cost and with almost as little trouble as a bed of vegetables. The seed may be purchased or collected locally and planted in drills in soil prepared in the same manner as for vegetable crops. Stocks thus raised can be left in the seedbed until it is convenient for the owner to plant it. This plan avoids possible damage to the stock during shipment from a commercial nursery or unforeseen delays in planting the stock after it is received. One-year-old hardwood stock varies in height from less than a foot to more than 4 feet. A tree's height growth during the first year usually indicates its future vitality. Thus the taller trees grown in the seedbed should be given preference in planting. In the case of a plantation of black locust in Indiana, where the planting stock was raised by the owner, the smaller stuff was about 3 feet and the larger 7 feet tall after two years' growth in the seedbed. The larger and smaller trees were planted separately on similar sites. After four years the 7-foot seedlings were 20 feet high, while the 3-foot seedlings were only 12 feet high.

Advantage could be taken of this characteristic by planting the more and the less vigorous trees in mixture, the shorter ones merely as fillers to be cut out when the stand becomes crowded, the taller trees to constitute the stand to be left until maturity.

Conifers are not so easily propagated as hardwoods, and it would ordinarily be best to purchase coniferous seedlings or transplants rather than raise the stock at home. Conifer stock should be purchased either from reputable nurserymen or from those State nurseries which offer it for sale. If a fairly large number of young plants are

desired, it is usually possible to obtain them at a reduced price if a contract is made with the nurseryman some time in advance. Lists of dealers in nursery stock may be secured from the Forest Service, Washington, D. C. Stock from local nurseries is usually preferable to that secured from a distance.

METHOD OF PLANTING.

FACTORS DETERMINING CHOICE OF METHOD.

The cost of the actual planting operation is one of the fundamental factors in fixing the final cost of the plantation, and so the method to be followed in this operation should be given careful consideration. What method should be applied depends upon the species and size of stock, character of site, condition of stock, and region.

If for any reason large stock with large root systems must be planted, such as hardwoods 2 or more years old or conifers several years old, holes must be dug either with a spade or mattock for each individual tree. But if smaller stock can be used a more rapid, cheaper method may be followed.

The character of the species alone may be the single factor in determining the method of planting. For example, the nut trees develop so deep a tap root that it is impracticable with them to adopt any method of planting except that of sowing the seed directly on the permanent site.

The character of the site alone may also determine the planting method. A very rocky situation may preclude all planting methods except that of digging a hole for each individual tree.

The condition of the particular stock to be planted may make one method preferable to another. If, for instance, the trees are received in poor condition, or if they happen to have a very poor root system, it may be necessary to plant them with particular care.

The region, together with the species, is an important factor in determining the planting method. The climate in one region may favor a given species more than that in another region, and hence more rapid, less careful methods of planting may be used in one region than in another.

DESCRIPTION OF METHODS.

Slit method.—The planting method which has probably been most often used is that known as the "slit method." A wedge-shaped hole is opened in the ground by inserting a spade and moving it backward and forward. The roots of the seedling or transplant are then inserted back of the spade in the cleft thus formed, the spade is removed, and the earth pressed with the foot firmly around the plant. A mattock is sometimes used instead of a spade. With this the soil may be loosened over a spot from 10 to 12 inches in diameter, and the cleft then made in the center of this loosened soil.

The slit method has proved very successful throughout the region of this report, both with hardwoods and with conifers.

Direct seeding.—The method of direct sowing of seed in rows on the planting site has been followed with much success. In a few cases walnut seed which during the previous winter had not been properly prepared by stratifying was sown in the spring with rather unsatisfactory results. A portion of the seed sprouted the first summer, but the larger part of it remained dormant in the soil through the following winter and then sprouted. Such cases as this merely emphasize the need for treating such seed before planting it.

Broadcast sowing also deserves some attention. In Iowa one plantation of green ash was started by broadcasting the seeds on ground prepared by plowing and harrowing and then covered by harrowing. The trees came up very thickly; after 17 years a sample plot 50 feet square showed 135 living and 63 dead trees. Ordinarily such good results could not be expected, but these figures show that a very dense stand may sometimes be secured by broadcast sowing. Similar results might be obtained with species other than green ash, but success is not as likely as in the case of other methods of sowing or planting.

Planting of sprouted nuts.—A rather novel but very successful method of planting black walnut was that followed by one planter in Indiana. He buried the walnuts in a shallow pit during the winter so that they might be subjected to the action of frost and moisture before planting. Upon uncovering the nuts the following spring he found that many of them had formed sprouts 3 or 4 inches long. These were planted on well-tilled ground by scooping out a little soil with the hands, a method similar to that of planting cabbage. This method reduces the possibility of fail places in a plantation, and may be used with species like black walnut, butternut, hickories, and oaks, wherever the nuts sprout before the planter is able to set them out. Sprouting does not in the least injure the quality of the seed, although it may necessitate such a method of planting as the one described.

Furrow method.—Another method is to plant young trees in a plowed furrow. This is rapid, and in good soil has proved successful with such hardwood trees as cottonwood, maple, and ash, and also with such coniferous trees as pine and spruce. It is especially applicable in the case of cottonwood and willow cuttings of 1 or 2 year old wood taken from old trees.

Individual hole method.—This method, which has not been used extensively, consists simply of digging a hole for each individual tree. It is undoubtedly the surest method, but at the same time the most expensive.

COSTS OF DIFFERENT METHODS.

Table 1 shows the cost of planting operations, exclusive of the cost of the stock itself, where different species and methods were used.

TABLE 1.—*Cost of planting with different species and methods.*

Case No.	Species.	Stock.	Method of planting.	Soil.	Cost per M.
1	Black locust	1-year seedlings	Holes dug	Yellow clay silt	$5.35
2	do	do	Slit method	Sand	1.25
3	Russian mulberry	do	do	Yellow clay silt	3.00
4	do	do	do	Sand	1.50
5	White pine	Wild stock 5 to 6 inches high.	Holes dug	Black loam	6.00
6	do	Seedlings	do	do	5.00
7	do	3-year seedlings	Slit method	do	3.00
8	do	1-year transplants	do	Yellow clay silt	3.00
9	do	2-year seedlings	Furrow plowed	Black loam	1.25
10	Black walnut	Seed	Small hole dug	do	1.00
11	do	do	Dropped in intersections made by corn marker.	do	.75
12	do	do	Pressed into ground	do	.50
13	do	do	Dropped into old corn hills.	do	.50
14	do	Seed, sprouted	Like cabbage plants	Black sandy loam	5.50
15	do	Seed	Furrow plowed	do	.50
16	White ash	3-year seedlings 6 to 8 feet tall.	Holes dug	Sand	7.85
17	do	1-year seedlings	Slit method	Black loam	2.00
18	do	do	do	Sand	2.00
19	do	do	do	do	1.50
20	do	do	Furrow	Black loam	2.00
21	Green ash	do	Slit method	do	1.00
22	do	Seed	Broadcast	Yellow clay loam	.50
23	Cottonwood	1-year seedlings	Slit method	Sand	1.50
24	do	Cuttings	Furrow	Black loam	.25
25	Norway spruce	2-year transplants	Holes dug	do	6.00
26	European larch	2-year seedlings	do	do	5.00
27	do	do	Slit method	do	3.00
28	do	do	do	do	1.00
29	Scotch pine	Seedlings	Holes dug	do	5.00
30	do	2-year seedlings	Slit method	do	3.00
31	do	4-year transplants	Furrow plowed	do	3.00
32	Soft maple	1-year seedlings	do	do	2.00
33	do	Seed	Hoe	do	.35
34	Bur oak	do	do	do	.35
35	White spruce	1-year transplants	Furrow	do	1.25

Table 1 is based largely on estimates of cost made by actual planters. Since in most cases no exact records were kept the figures are only approximate, though they show very closely the relative costs of the different methods of planting. In order of cheapness the four principal methods rank as follows: Direct sowing of seed; planting in furrow; slit method; digging a hole for each tree. Apparent discrepancies in the table are due to the special conditions of each case, such as topography and soil, and the care exercised by individual planters.

MERITS OF THE DIFFERENT METHODS.

For those species to which it is adapted, direct sowing has the advantages of rapidity and cheapness. On the other hand, the seed may be eaten by birds or rodents, or it may be defective. Again, the small size of the trees during the first year makes proper cultivation difficult, nor can the method be relied upon in unfavorable sites or seasons. In spite of these objections, however, it has proved success-

ful with walnut, butternut, ash, silver maple, red and bur oaks, black cherry, and white, Scotch, red, and pitch pines.

The seed of the nut trees (walnut, butternut, the hickories, and black and red oaks) should either be planted in the autumn or, what is better, buried in a shallow, rodent-proof pit out of doors during the winter, and then planted on the permanent site in the following spring. Seed thus buried during winter is said to be "stratified." Silver maple seed must be gathered during the spring in which it is planted. Seed of the remaining species mentioned in the preceding paragraph should be gathered during the fall or winter previous to planting and stored away until spring. Pine seed is best stored in a sealed fruit jar or other air-tight container, though it, and also cherry seed, may be stored in cloth sacks hung out of the reach of rodents in a cool, well-ventilated room. Stables, however, should not be used for storage purposes. Ash seed is best stored with an equal volume of moist sand in boxes kept in some cool place.

Planting in furrows is rapid and is the least expensive of all methods for seedlings, transplants, or cuttings. It has proved successful with both hardwoods and conifers, but there is danger that the trees will not be set deeply enough in the ground. The method of covering the roots—simply plowing a second furrow toward them—is very likely to result in either covering the young trees or leaving the roots exposed. Frequently the earth is not well firmed over the roots, though this may be done after the plow has passed. The method can be practiced, of course, only where the ground permits of plowing. Because of its low cost it is recommended, if carefully done, for small seedlings or transplants without a pronounced taproot system, on good soil, and also for cottonwood and willow when propagated by cuttings.

The slit method of planting has proved very successful, and is fairly rapid and cheap. It may be recommended for small stock of nearly all species unless the soil is very poor or uncommonly dry at the time of planting, or unless the stock used is exceptionally high priced or in poor condition.

Digging a hole for each tree is necessary under such conditions as those just cited. This is an expensive operation, however, and should not be used where any other method would prove successful. In case 16 in Table 1 the stock used consisted of 3-year-old seedlings between 6 and 8 feet tall. As compared with the other cases the cost of planting was very high. The soil was almost a pure sand, which made digging easy, but a hole 2 feet deep had to be dug for each tree. The trees grew so poorly at first that after a couple of years the owner cut them back to the ground. Sprouts have come up from the stumps, but these are only a little larger than some 1-year-old seedlings set out three years later on the same site. Large stock is only to be recommended where hogs are to run among the trees soon after planting.

TIME OF PLANTING.

Practically all of the plantations examined in the region have been started in the spring, which seems the best season for setting out seedlings on the permanent site. As compared with autumn planting, spring planting has at least two distinct advantages—the stock has a whole growing season in which to become established before being subjected to the rigors of winter, and it is not subject to the immediate danger of being heaved out of the ground by alternate freezing and thawing. On the other hand, a dry season immediately after the trees are set out in the spring may prove fatal to the plantation.

In the case of direct sowing, the time of planting is best determined by some characteristic of the seed to be planted, particularly the time of ripening. Silver maple and elm seed, for example, lose their vitality soon after they ripen in the spring and must be sown at the latter time. Walnut, butternut, hickory nuts, and red oak seed must be kept moist for a considerable period before they will germinate well; hence they must either be planted in the autumn or else stored over winter in some place where they will come in contact with damp soil. Any freezing which occurs during this period will be helpful in opening the hard shells.

Cloudy days should be selected for planting, especially in the case of conifers. Exposure to the sun, even for a short time, will kill the young roots, and thus the plantation will fail at the very start. The roots of the young trees, whether hardwoods or conifers, should be kept moist up to the very moment when they are planted on the permanent site. The stock may be carried to the field in a bucket, with the roots immersed in water, or the roots of a bunch of trees may be wrapped in wet burlap, one tree being drawn out at a time and planted.

PREPARATION OF THE SOIL.

Plowing and harrowing the planting site before setting out the trees is a wise practice. It puts the soil in good tilth, facilitates planting, conserves soil moisture, increases the proportion of successful trees, and induces rapid initial growth. On very sandy soils which do not support a heavy sod of grass, however, preparation is not necessary; and on very steep slopes and among rocks or large roots may be too expensive.

Fall seems to be the best time to prepare the ground, since the soil is thus exposed to the action of the winter frost, and has time to settle before receiving the young trees. The trees in a 5-year-old plantation of black locust in southern Michigan, on fall-plowed ground, were fully as large as those in a 6-year-old plantation set on an adjoining strip plowed in the spring.

SPACING.

The proper spacing for trees in a plantation depends largely on the habit of the species and the character of the site. In general, the more tolerant the trees and the more unfavorable the site the closer should be the spacing. White pine is so tolerant that it must be planted as closely as 4 by 4 feet, in order to have the lower branches killed by shading at an early age. Close-spaced stands must be thinned sooner than open-spaced ones, and if the owner does not intend to make such a thinning when needed he should use a wider spacing. With practically all species close spacing requires a thinning before the stand is 20 years old, and in the case of some, especially intolerant or rapid-growing trees, such as cottonwood, by the time it is 10 years old. The trees removed in the early thinnings required by close spacing would usually be unmerchantable; hence, if the site is favorable, a wider spacing is usually best. Wide spacing, moreover, reduces initial cost and will give larger trees than can be grown in the same time in a closely spaced plantation in which early thinnings are not made.

On the less favorable sites, however, close spacing is best. The greater number of trees per acre offsets the higher mortality among the young plants on poor situations and also gives a thicker crown cover, and hence better protection of the soil. The relatively large amount of falling leaves and litter, moreover, mixes with the soil, thus actually improving it.

Close spacing gives clearer but comparatively slender boled trees; wide spacing results in more or less branchy trees of comparatively large diameter. This is well illustrated in the case of two plantations of white pine near Clermont, Iowa, on very similar sites. In one of them the trees were originally spaced 1 by 6½ feet and in the other 16 by 16 feet. When 43 years old the trees planted 1 by 6½ feet had reached an average diameter of 7½ inches and an average height of 53 feet; the lower branches were dead to a height of from 20 to 30 feet and were falling off. At the same age the trees planted 16 by 16 feet had reached an average diameter of 12.3 inches and an average height of 60 feet, and though the lower branches were dead to a height of from 20 to 30 feet they were still persisting. Of two plantations of European larch near Sac City, Iowa, on similar sites, one spaced 8 by 8 feet has, after 28 years, reached an average diameter of 7.6 inches and a height of 47 feet, with the lower branches dead to a height of from 20 to 30 feet. The other, spaced 10 by 12 feet, at the same age shows an average tree diameter of 9.2 inches and a height of 43 feet, the trees having been pruned artificially to a height of 20 feet.

Old plantations have done much to indicate the relative spacings to which different species are adapted. These spacings are given under the discussions of the respective species.

CARE OF PLANTATIONS.

CULTIVATION.

Most forest plantations should be cultivated for two or three years after being set out. On the heavy soils of the treeless and hardwood regions cultivation becomes almost necessary. Though even on these latter soils the trees will survive without cultivation, they take a number of years to become well established, and meantime make very little height growth. If cultivated, however, they become well established during the first or second season and grow vigorously in height during this time. This contrast is brought out by two plantations of green ash, one in Iowa and one in Ohio. The soils in the two regions, though somewhat different in character, are both conducive to the growth of the species. In the Iowa plantation the trees were well cultivated and had reached an average height of 9 to 10 feet when only 4 years old. Cultivation was impossible in the Ohio plantation, because the soil was full of old roots; in consequence a heavy growth of grass came in and the trees, when 8 years old, had reached a height of only 8 feet.

Cultivation serves several purposes. It conserves soil moisture, keeps out grass and weeds which would ordinarily compete with the trees for moisture, hastens the establishment and growth of the seedlings, lessens mortality among the planted stock, and shortens the rotation. This last point is of special importance in commercial plantations of the fence-post trees, such as hardy catalpa, European larch, black locust, Russian mulberry, and Osage orange, grown on a rotation of from 15 to 25 years on soil with an annual rental value of $4 to $6 per acre.

On poor sandy or rocky soil, where trees of commercial value can not be produced in less than 50 years, cultivation is generally not advisable. On such soils the growth of grass and weeds is usually insufficient to interfere very much with the growth of the trees, and the expense of cultivation, when figured at compound interest for 40 or 50 years, more than offsets the value of the resulting increased growth.

In cultivating a plantation there is always the danger of continuing the operation too late in the season. Forest trees, like fruit trees, are subject to damage by heavy, early frosts, and, if their wood is particularly succulent at the time when these occur, may be severely injured. Late cultivation is conducive to this condition of the wood, and no work of the kind should be continued beyond the first or middle of July. The grass or other vegetation coming in after this serves a good purpose in drying out the soil, thus checking the growth of the trees and hardening their wood. The danger of late cultivation can not be emphasized too strongly, since young

plantations, even of the hardy black walnut, have been killed back to the ground by severe early frosts and winter freezing when cultivation was continued too late in the growing season.

It is not necessary that the entire cost of cultivation be borne by the plantation. Field crops of corn, potatoes, or beans may be grown between the rows for the first one or two years. These will not only yield a revenue to the owner, but their cultivatiion will benefit the young trees. Sometimes all of the cost of cultivating can be charged against the field crop, making a considerable difference in the final cost of the plantation.

The number of years in which cultivation is necessary and the amount of it each year will depend, of course, upon the rapidity of growth of the species planted and the spacing of the trees in the plantation. Some planters have found two cultivations a year for three years sufficient, except under unusually trying conditions. A three-year period should be ample, with possibly three or four cultivations during each of the first two seasons. The work may be done at first with a two-horse cultivator, and later, when the trees become larger, with a one-horse cultivator.

THINNING.

Every forest plantation reaches a condition after a few years when some of the standing trees should be cut out. The removal of undesirable trees is called a thinning. The principle is the same as that applied by truck gardeners to vegetable crops which are thinned out in order to get the best development of a portion of the crop rather than a meager development of the whole. The struggle for existence between the trees of the stand first induces rapid height growth and kills the lower branches, but, if allowed to continue, the more vigorous trees are prevented from making their best diameter growth by the presence of the less vigorous ones.

Where there is a poor market for the product from thinnings the operation will scarcely pay for itself; where the market is good, however, thinnings have been made at a net gain of from 10 cents to $2 per cord.[1] In the more widely spaced plantations thinnings will not be necessary until the product is of merchantable size. The future, moreover, promises a better market for small-sized material than exists at present, which will make thinnings profitable in stands in which now they would not be. In small plantations thinnings may be carried on by the owner at odd times at no cost other than his own labor. When poles are cut for some farm use a little care in their selection looking to the betterment of the stand will insure a crude form of thinning.

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[1] Bulletin No. 2, State Forester's Office, Massachusetts.

The presence of dead or dying trees in the stand, a very dense crown cover, or an apparent stagnation in the growth of the living trees indicates that a thinning is needed. The usual practice is to thin when the product is of sufficient size to pay for the operation and to repeat the process thereafter as often as the material has accumulated in sufficient quantity to again pay for the cost. Many plantations, however, need their first thinning before they reach this state. Silver maple, black locust, and other species have a decided tendency to grow toward openings in the crown canopy, and in their efforts to reach these the trunks become crooked. Under such conditions a thinning should be made whether the operation will pay for itself or not. The first thinning may be needed by the time the stand is 10 years old.

As a rule, trees of the least potential value should be the ones removed in a thinning. In the early life of a stand the trees range themselves into several crown classes—dominant, codominant, intermediate, suppressed, and dead. The dominant trees are the tallest ones, whose crowns receive almost complete sunlight; codominant trees are those of slightly less height, with relatively narrow crowns which are not fully exposed to sunlight; intermediate trees are considerably smaller than those of the first two classes, but still healthy, because their crowns continue to occupy open spaces in the canopy; suppressed trees are those hopelessly behind in height growth, and which will eventually be killed by the shade of the other trees. The trees which remain after a thinning should, as a rule, be those which are most vigorous, of the best form, and presumably of the highest final market value. This does not mean that no codominant or dominant trees should ever be cut, or that no intermediate and suppressed trees be allowed to remain. High-grade trees must sometimes be cut to obtain the proper opening of the crown canopy, and inferior trees may serve the useful purpose of shading the soil, thus tending to retard evaporation and prevent the growth of harmful vegetation on the forest floor. Except where needed for soil shading, however, suppressed and intermediate trees should generally be thinned in preference to the larger trees of the first two classes. When it can be done cheaply dead trees should be removed in order to rid the stand of material likely to increase the danger from fire.

The extent to which the crown of a stand may be opened depends largely upon the rate of growth of the species and their demand for light. In general, openings should not be so large that they will not close again within from three to five years by the growth of the remaining crowns. Rapid-growing trees, such as cottonwood or silver maple, should have their crowns opened to a much greater extent than

stands of slower growing species, such as ash, oak, or walnut. Intolerant trees, such as cottonwood, European larch, black locust, or black walnut, require large openings in the crown cover. Cottonwood and European larch in particular die for no apparent cause except insufficient light, even when apparently receiving an abundance. For white pine and Norway spruce the openings need not be large.

There are no instances in this country where thinnings have been systematically carried on, and for this reason it is not possible to cite examples of their effect. The comparative size of trees grown in open-spaced and close-spaced stands, however, is something of an indication of the results to be expected from thinning, and a few examples of this sort are given in Table 2. Comparisons should be made, of course, only between stands or rows of nearly the same age.

TABLE 2.—*Size of trees in open and close spaced stands.*

European larch.				White pine.				Cottonwood.			
Nature of stand.	Age.	Spacing.	Average diameter breast high.	Nature of stand.	Age.	Spacing.	Average diameter breast high.	Nature of stand.	Age.	Spacing.	Average diameter breast high.
	Yrs.	*Feet.*	*Inches.*		*Yrs.*	*Feet.*	*Inches.*		*Yrs.*	*Feet.*	*Inches.*
Grove	28	8 x 8	7.6	Grove	35	6 x 7	8.8	Grove	12	5½ x 8	8.4
Do	28	10 x 12	9.2	Do	37	8 x 9	9.7	Do	13	4 x 5	3.9
Row	28	(1)	10.6	Do	39	4 x 4	8.1	Do	35	8½ x 8½	13.3
Grove	35	8 x 8	10.0	Do	43	16 x 16	12.3	Row	35	(3)	19.3
Do	35	7½ x 7½	11.2	Do	43	1 x 6½	7.5	Grove	36	5 x 10	13.4
Do	37	8 x 8	10.0	Row	53	(2)	14.1	Do	40	2 x 36	17.6
Do	35	3 x 7	7.4	Grove	53	6 x 7	11.1	Do	41	6 x 6	12.3
Do	39	3¾ x 3¾	7.0								
Do	40	4 x 4	8.3								

[1] 5 feet apart in row. [2] Trees 6 feet apart. [3] 2 to 4 feet apart in row.

PRUNING.

Pruning is the removal of living or dead branches from a tree. The purpose is to improve the tree's form; to increase growth in its leading shoot by eliminating some of the lateral shoots and to improve the quality of the lumber by getting rid of the source of knots.

Most trees in forest plantations, especially those closely spaced at the start, will prune themselves; the additional value gained by pruning them by hand is usually not sufficient to pay for the operation. The cost, therefore, would have to be reckoned as a fixed charge, to run at interest, against the final cost of the plantation. In small plantations, however, it may be possible for the owner himself to do the pruning at odd times, and thus avoid an additional charge. Side branches can not well be pruned to a greater height than a man can reach from the ground with an axe, and this amount of pruning will scarcely have much effect in increasing the stumpage value of the timber.

Another objection to pruning is the danger of overdoing it. If a tree is pruned too far up it may become top heavy and be broken off in a severe wind. Catalpa, ash, and black cherry are particularly susceptible to injury in this way. The stems of young black cherry and ash, when pruned far up, bend over by their own weight nearly at right angles. Sucker sprouts then shoot up from the bent stems, making a deformed tree. In a stand of black cherry 8 years old in Indiana, where the trees were pruned to a whip, 11 per cent had been broken off by the wind.

Pruning also reduces the amount of leaf surface, the food-making part of the tree, and hence reduces its rate of growth.

Especially valuable species and trees with very persistent branches should be trimmed at least of their dead branches and sometimes of their living ones. Of the species commonly planted, white pine, black walnut, hardy catalpa, and black locust sometimes need pruning.

The lower branches of white pine are large and persist for many years after dying. Sometimes, but not as a rule, it will be profitable to prune the best trees in the stand by simply knocking off the limbs with an axe after they are dead and have become brittle. Black walnut seldom needs pruning, though occasionally dead branches persist for a number of years which are likely to form loose knots in the lumber. Such branches should be removed. Hardy catalpa has very persistent branches, though the presence of knots in fence posts, the chief product of catalpa plantations, scarcely impairs their value. The dead branches are objectionable, however, because they become loose and allow the entrance of wood-rotting fungi. Since, therefore, these branches are a menace, they should be removed. Catalpa, moreover, does not form a terminal bud, but ordinarily develops three buds at each node. From those at the node nearest the tip of the last year's shoot three new shoots arise, any one of which may develop into a leader. In order to increase the development of one of these shoots and thus control the tree's form, one or both of the other two shoots on the node should be removed. An effective and cheap way of doing this is to pinch off these shoots just as they are developing from the buds. Black locust ordinarily prunes itself readily, but when widely spaced the main stem often forks into two or more main branches. In one young plantation of black locust in Illinois, spaced 8 by 11 feet, fully 43 per cent of the trees showed this fault. Such trees should if possible be pruned of all but one of their leaders.

The lower branches of Norway spruce are very persistent, but not very large; hence for ordinary purposes the tree requires no pruning. The ashes ordinarily prune themselves of their lower

branches, but the leader from year to year seems to develop as commonly from one of the lateral buds as from the terminal one, resulting in a crooked bole. The ash plantations examined have grown too slowly to make pruning a profitable operation, but if especially straight stuff is desired it can be obtained either by very close spacing or by pruning. Ash will grow fairly straight if spaced closely, and pruning should accomplish the same result as close spacing. One method of pruning is to cut off each year the lateral shoots which threaten to compete with the leader; another is to pinch off the lateral buds formed near the tip on the terminal shoot.

The branches of European larch die early, but are very persistent. Pruning this tree does not pay, however, because the products of the plantation (chiefly posts and poles) are almost, if not fully, as valuable when somewhat knotty as when clear.

Cottonwood prunes itself exceptionally well, and soft maple, black cherry, and Scotch pine also lose their branches readily. The oaks, as a rule, are not good self-pruners, but they grow so slowly that pruning is not a profitable operation.

MIXTURES.

Comparatively few plantations of mixed species have been set out in the region under discussion, and in the few cases where this has been done the mixture has usually proved unsuccessful. This has been due, however, more to the planters' ignorance of the requirements of the species planted than to any essentail defect in the method itself. A mixture of two or more species is often desirable. Some trees, such as cottonwood and European larch, need to be spaced widely, while others, like black walnut and black locust, have such a scant foliage that they do not shade the ground completely enough to prevent the growth of a heavy sod of grass. In such cases a mixture will more completely utilize the area planted, thus increasing the yield, and at the same time will bring about better forest conditions in the plantation.

Mixtures are desirable for other reasons. Planting stock of such species as white pine and European larch is expensive, and a less valuable species mixed with the main crop, and removed later in thinnings, will keep down the first cost. If a species to be planted is susceptible to serious insect or fungous attack, as is white pine or black locust, the mixture of another species not susceptible will provide for a stand of trees on the area in case the pine or locust is killed. When such species as European larch, white pine, or black walnut are widely spaced, in order to promote the most rapid growth, it may be advisable to interspace the area with some more tolerant and slower-growing species.

A number of mixtures are given below which should prove successful on soils adapted to both species of the mixture, and which

are likely to have one or more of the advantages cited. The principal species in each mixture is named first; and where they take equal rank the fact is indicated by an asterisk (*):

1. Cottonwood and silver maple.
2. Cottonwood and Norway spruce.
3. Cottonwood and white spruce.
4. Cottonwood and green ash.
5. * European larch and white pine.
6. * European larch and red oak.
7. European larch and white spruce.
8. * European larch and Norway spruce.
9. White pine and Scotch pine.
10. * White pine and Norway pine.
11. White pine and hard maple.
12. White pine and red oak.
13. Black walnut and white spruce.
14. Old open stands of black walnut underplanted with white pine.

Many of the old groves, particularly in Iowa, are of soft maple. These may be gradually replaced by underplanting with white spruce and removing the maple.

PROTECTION.

INSECTS.

The locust borer has completely destroyed many plantations of black locust; the white-pine weevil kills the leading shoot of white pine; the gipsy and brown-tail moths defoliate the hardwoods, particularly the oaks, and in some cases have attacked conifers; while the sawfly has defoliated and killed much of the native larch and has attacked also the European larch. Before setting out any trees the prospective planter should communicate with the Bureau of Entomology of the Department of Agriculture, or with the State experiment station, in order to find out whether insect enemies of the species he proposes to plant are prevalent in the neighborhood. At the first sign of insects in an established plantation the owner should likewise communicate with the Bureau of Entomology to ascertain the best methods of combating them.

FIELD MICE AND RABBITS.

Young trees are sometimes girdled by field mice and rabbits. Where these pests are numerous it is almost impossible to prevent them from eating the bark of trees during the winter when green food of other kinds is absent. If the grass around the tree is killed by cultivation there will be less danger from field mice, since these work largely under the grass covering. Poisoning is not always an efficient method of getting rid either of mice or rabbits; and poisoned food may kill some valuable domestic animal.

WIND, SNOW, AND FROST.

High winds often break or twist off the trees in a plantation. Such damage may be avoided to some extent by planting wind-firm species around the edge of the plantation, or by spacing the trees more closely on the windward sides.

Snow and frost may also cause considerable damage; the former weighs down and breaks off branches and leaders; the latter, when occurring late in spring or early in autumn, may kill the succulent wood. Damage from snow is less likely with hardwood trees than with conifers, because the bare branches of the former do not permit as much of it to accumulate. Frost damage may be partly avoided by planting hardy species or by utilizing sites on north, northeast, or northwest slopes, where growth begins comparatively late in spring and stops early in the fall. Low sites on which there is poor circulation of air should be avoided.

GRAZING ANIMALS.

Sheep, cattle, or horses should never be allowed in a young plantation. They browse upon leaves and tender shoots and trample the trees, which become crooked, branchy, and dwarfed. If pasturing is continued the trees will eventually be killed. Bulletin 200 of the Wooster (Ohio) Agricultural Experiment Station, sums up, for Ohio, the damage from this source:

> The acres of young forest which have been needlessly destroyed within the State foot up into the millions. Their value, had they been protected from live stock, would to-day amount to double the sum which has been realized from the pasture. This is demonstrable, for the investigations of the experiment station have shown that the value of young forest-tree growth exceeds the value of woodland pasture more than two to one. There is no such thing as profitable woodland pasture. The combination of grass and forest is incompatible. Cattle derive but little, if any, benefit from browsing or from the shaded innutritious grasses, but they do damage the trees. The losses from this practice are larger to-day than ever before because of the constantly increasing value of the trees which are destroyed.

In a plantation of green ash at Kanawha, Iowa, trees which had been protected from cattle were from 10 to 17 feet high, while others of the same age which had been browsed by cattle were for the most part only 4 feet high. In a 5-year-old plantation of black locust in Michigan, grazed by both sheep and cattle, ungrazed trees had reached an average height of from 8 to 14 feet, when those browsed by the stock were only from 2 to 3 feet high. In a 10-year-old plantation of black walnut in Indiana, grazed by cattle, 25 per cent of the living trees had been broken by stock, and averaged from 5 to 6 feet in height; the unbroken trees were from 19 to 25 feet high. The owner stated that the trees were pretty well tramped out at one time, which accounts for the fact that of the trees originally planted 78 per cent are now missing.

In older plantations the damage done by stock consists largely in packing of the soil. As a result of the stock running at large, the humus is destroyed and the roots of the trees exposed and perhaps wounded, while the soil becomes impervious to water. The stand, of course, suffers accordingly. Moreover, fungi may enter the trees through wounds around the base or in the roots.

Hogs root up the soil and expose the tree roots to the air, or even devour the roots themselves. In Iowa hogs completely destroyed one plantation of European larch in this way. Young trees are very likely to be rooted completely out of the ground.

If shade and protection for stock can be obtained in no other way, the animals can be admitted to one portion of a plantation and excluded entirely from the other portions, which should be devoted exclusively to the growing of timber.

FIRE.

Whenever there is any danger from fire, definite steps should be taken to guard against it. Most of the smaller plantations already established are located near the owner's residence, where they can be kept under observation, but in some of the larger plantations, where a close watch has not been kept, fires have done considerable damage. The owner of a large plantation should certainly make some provision to protect it, especially if it is near a railroad or is likely to be visited by picnic parties. Fire lines might be constructed, and a general watch should always be kept. Roads often make good fire lines, and when so used should be kept free from grass. Where no roads pass through the tract, fire lines from 6 to 8 feet wide may be plowed around the area, or else a strip of this width burned or otherwise kept cleared of all inflammable material. A fire line ceases to be a fire line wherever it becomes covered with litter or a heavy growth of grass.

DISEASES.

The diseases to which the different kinds of trees are subject and the methods of combating them can best be ascertained by consulting with the Office of Forest Pathology, Bureau of Plant Industry, Washington, D. C., or the State experiment station. Prospective planters are strongly advised to do this before purchasing their trees. Nursery stock, particularly that from abroad, is often diseased.

MISTAKES IN TREE PLANTING.

Forest plantations have too often been started by those with little knowledge of the requirements of the trees set out, and who were often influenced in their choice of species by advertisements of tree agents. It is little wonder, then, that mistakes have been made. Planting operations should not be undertaken until a thorough inquiry has convinced the owner as to which species is best adapted to his purpose and which will succeed on the planting site selected. Advice and aid can be obtained by prospective planters from their respective State foresters, a list of whom is given in the Appendix. The Forest Service of the United States Department of Agriculture also gives advice in regard to the best species to plant and methods of planting.

To enable planters to avoid errors made by other planters in the past, some of those observed in the course of the study are described:

(1) Planting European larch and silver maple in mixture killed the larch, which is the more valuable tree of the two.

(2) Planting black walnut under green ash killed the walnut, which must have full sunlight in order to succeed.

(3) Catalpa planted under black locust grew very slowly. Catalpa requires full sunlight for good growth.

(4) European larch planted under catalpa did not live. Larch requires full sunlight.

(5) Box elder planted in mixture with green ash at first grew more rapidly than the other species and shaded out much of it, though ash is the more valuable tree.

(6) Cottonwood planted on a gravel knoll did not live. The situation was too dry for it.

(7). The roots of cottonwood planted in a "blowout" in sandy soil were exposed by the shifting of the sand; the trees, when observed, were very scrubby and dying.

(8) Catalpa planted on a gravel knoll was only about 2 feet tall after 7 years. Such soil is not suited to catalpa.

(9) Catalpa trees planted in soil with a hardpan about 8 inches below the surface were only 3 or 4 feet high after 7 years of growth. Catalpa requires a deeper, well-drained soil.

(10) Ash planted in a "blowout" in pure sand, while still alive after 5 years, was not much larger than when set out. A pure sandy soil is not suited to ash.

(11) Black walnut and green ash planted in low wet ground made a scrubby growth. The soil was not well enough drained for either of them.

(12) Osage orange planted in pure sand failed to survive. Osage orange requires a fairly good soil.

(13) Three-year-old ash stock, which cost a good deal in the first place, and had to be set in by the most expensive methods, grew so poorly that it was necessary to cut the trees back to the ground after a couple of years. The stock was too large when planted to succeed well.

YIELDS AND RETURNS.

The yields in products and the money returns to be expected from plantations are given in the tables for individual species (pp. 24 to 32).

Existing plantations do not, as a rule, afford a good basis for estimating possible yields and returns from plantations started now, for species have often been planted on inhospitable sites, spacing has been too wide or too close, almost no attention has been given to proper thinnings, and live stock has been allowed to run among the trees. Moreover, the cost of planting stock has often been excessive; $20 a thousand for European larch and $20 to $25 a thousand for hardy catalpa is unduly high. It has been practically impossible to obtain wholly reliable cost data for a given plantation or the exact amount of products secured from it prior to the time when it was examined. In many cases the original planters have died or moved away, or have kept no accurate record of costs or returns.

In reckoning the cost of an income from plantations, interest has been calculated at 3 per cent, compounded annually. The land values and tax rate assumed are undoubtedly lower than those now in effect, but it should be remembered that neither averaged as high during the

life of the plantation as the present figure. In estimating future returns from plantations started to-day, the land values assumed should be as high as those at present in effect, and even somewhat higher if the general trend in land values of the region is upward.

Even at the low interest rate of 3 per cent growing trees on land worth $100 to $150 an acre for the sole purpose of obtaining lumber and other products will not, at the present stumpage prices, prove a profitable undertaking. But if the plantation serves also as a protection against wind such planting should pay very well. It has been found that due to the protection afforded by the most efficient grove windbreaks the yield in farm crops is increased to the extent of that grown on a strip three times as wide as the height of the trees.[1] The protection afforded by his grove of ash and maple has been estimated by one farmer in Iowa to save him $300 per year in feed for his stock.

In view of advancing stumpage prices, it seems safe to estimate the yields from future plantations as being equal at least to the highest yields from plantations made in the past on similar sites. Timber products, moreover, will almost certainly advance in value, though it is open to question whether this advance will be sufficient to offset the rapidly increasing value of the land.

INDIVIDUAL SPECIES.

COMMON COTTONWOOD (Populus deltoides Marsh.).

The common cottonwood is the most rapid growing of the trees commonly planted. It is not exacting in regard to soil, but requires an abundance of moisture. It is very hardy and is especially adapted for planting on poor, sandy river-bottom sites where the water table is within from 4 to 6 feet of the surface. When 30 or 40 years old the trees begin to die in the tops and the stand to deteriorate. For its best development cottonwood requires an abundance of sunlight, and, if planted in groves, a wide spacing of 12 by 12 to 12 by 15 feet is needed. Closer spacing not only adds to the initial expense but results in the death of many trees from crowding before they are large enough to be of much value. When planted in groves, however, cottonwood should be underplanted with some such species as silver maple, in order fully to utilize the ground. This would insure better forest conditions than are generally found in open groves of pure cottonwood, and would promote the production of clear timber of a fairly high value. The main product derived from cottonwood is lumber, and from maple, cordwood.

A stumpage value for cottonwood of $8 per thousand board feet is considered low. In Iowa it brings from $10 to $12. For inside dimension timbers cottonwood is as good as higher priced material. The timber has been used for corncribs and barns. Heavy cottonwood planks, because of their toughness when seasoned, are especially desirable for the sides of horses' stalls.

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[1] Forest Service Bulletin 86, "Windbreaks."

Cottonwood cordwood is difficult to split after it becomes dry, but considerable quantities, in addition to lumber, are produced in groves or in rows. A value of $2.50 per cord on the stump is considered a fair average for the tree throughout the region in which it has been planted most extensively.

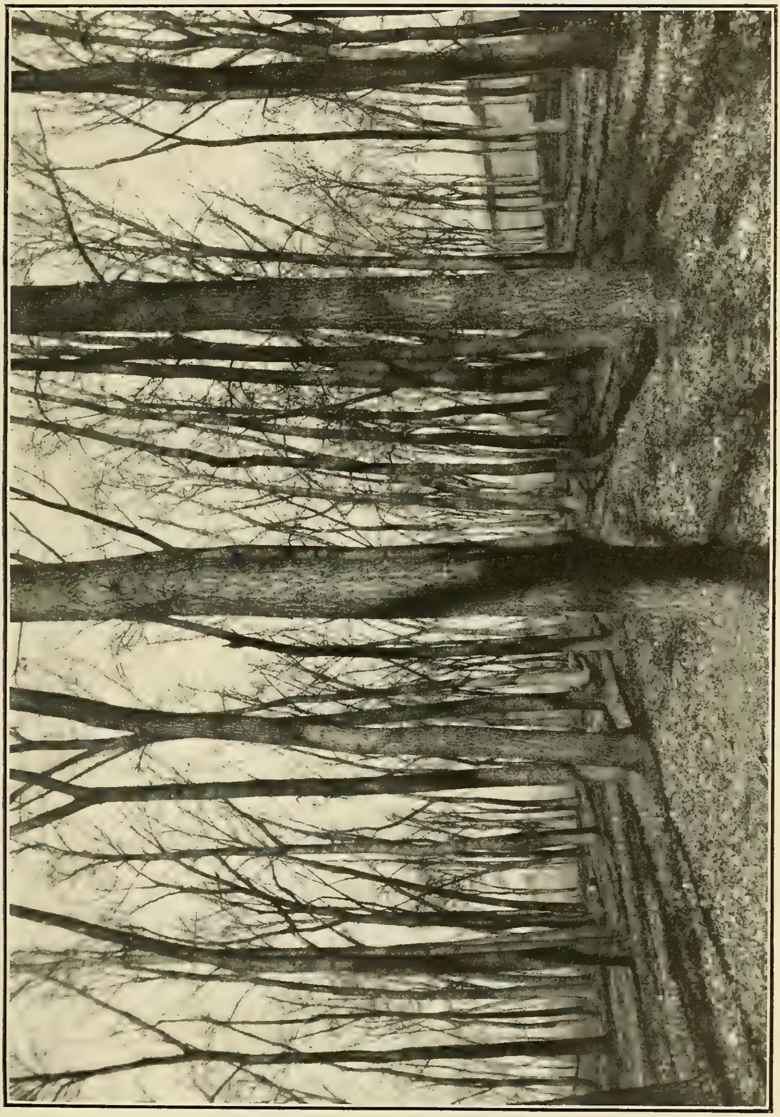
Cottonwood is easily propagated from cuttings. It has done well in Iowa, and probably would thrive throughout the whole eastern region, even to the New England States.

Table 3 gives the yield and value of cottonwood in Iowa. In this table and in the tables for the other species the total costs to date are determined by means of the formula, $\text{Cost} = (S+E+C)\,1.0p^n - (S+E)$, where S = average value of land per acre, E = capitalized value of taxes $= \dfrac{\text{Annual taxes}}{\text{rate of interest}}$, C = cost of initial operations (preparation of soil, cost of stock, planting, and cultivation), and $1.0p^n$ = amount of $1 compounded annually at 3 per cent for a period equal to the age of the plantation. Total profit or loss per acre equals the amount by which the present value of products per acre exceeds or falls below the total amount of costs to date when computed at 3 per cent compound interest. Positive amounts are an excess profit above 3 per cent; negative amounts indicate the sums by which the profit fails to equal 3 per cent. Annual profit or loss per acre equals the total profit or loss per acre divided by the amount of $1 per annum at 3 per cent compound interest for a period equal to age of plantation.

TABLE 3.—*Yield and value of cottonwood (Populus deltoides) in Iowa.*

Age.	Soil.	Original spacing.	Present number of trees per acre.	Average diameter breast high.	Average height.	Yield per acre. Timber.	Yield per acre. Cordwood [1] (90 solid cu. ft.=1 cord=128 stacked cu. ft.).	Average value of land per acre during life of plantation.	Total amount of costs per acre to date.	Present value of products per acre (includes value of thinnings).	Profit (+) or loss (−) per acre. Total.	Profit (+) or loss (−) per acre. Annual.
Yrs.		*Ft.*		*Ins.*	*Ft.*	*Bd. ft.*	*Cords.*					
12	Sandy black loam...	5½ x 8	372	8.4	54	3,900	23.79	$70.00	$39.90	$90.68	+$50.78	+$3.58
17	Black loam..........	5 x 8	291	9.2	66	10,350	16.37	70.00	63.24	123.72	+ 60.48	+ 2.78
28	.....do..............	5 x 6	204	11.4	56	12,320	17.38	65.00	100.32	199.33	+ 99.01	+ 2.30
29	.....do..............	2½ x 3	370	10.0	58	10,860	29.17	60.00	102.09	159.80	+ 57.71	+ 1.27
30	.....do..............	6½ x 7½	66	13.9	68	6,400	7.19	60.00	113.00	69.18	− 43.82	− .92
34	.....do..............	6 x 7½	126	14.5	87	23,850	12.20	50.00	103.70	221.30	+117.60	+ 2.04
34	Clay loam...........	7 x 7	{[2] 45, [3] 273}	14.0	85	10,850	59.07	20.00	55.49	234.48	+178.99	+ 4.06
35	Loamy sand........	8½ x 8½	137	13.3	77	24,500	9.34	40.00	87.77	456.85	+369.08	+ 6.10
35	Black loam..........	8 x 8	160	12.1	72	10,850	17.69	50.00	119.92	131.03	+ 11.11	+ .18
36	.....do..............	5 x 10	125	13.4	74	15,820	6.35	60.00	144.25	142.43	− 1.82	− .03
40	Quite sandy loam...	2 x 36	233	17.6	100	49,926	55.47	40.00	116.88	538.07	+421.19	+ 5.58
41	Black sandy loam...	6 x 6	193	12.3	93	14,700	7.74	30.00	92.50	136.95	+ 44.45	+ .57
43	Black loam..........	8 x 8	74	15.9	71	12,600	5.38	40.00	135.67	115.25	− 20.42	− .25
50	Black sandy loam...	8 x 8	89	13.9	65	15,500	......	30.00	136.73	124.25	− 12.48	− .11
[4] 35	Black loam..........	....	137	19.3	82	32,900	29.41	50.00	106.33	336.50	+230.17	+ 3.81
[4] 40	.....do..............	....	83	17.1	71	16,000	3.83	40.00	107.54	137.60	+ 30.06	+ .40

[1] In addition to the board feet shown in preceding column.
[2] Cottonwood.
[3] Maple.
[4] Single rows reckoned as 50 feet wide by 871 feet long=1 acre.



COTTONWOOD PLANTATION, IOWA. TREES MATURE AND LARGE ENOUGH FOR SAWING INTO DIMENSION TIMBERS.

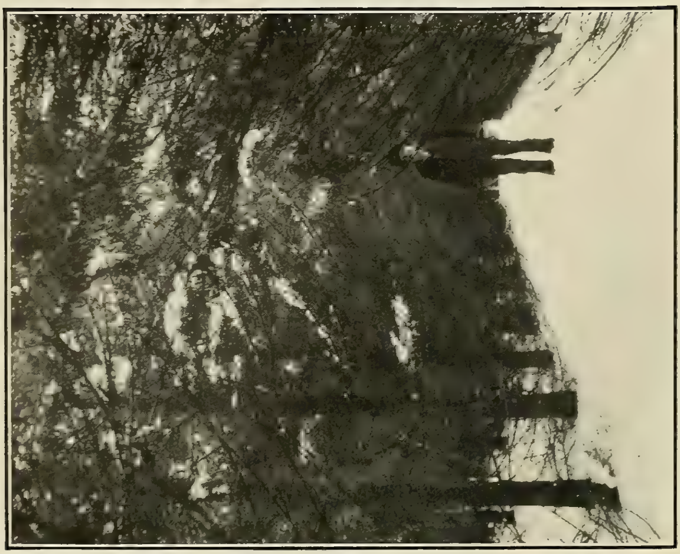


FIG. 1.—NORWAY SPRUCE PLANTATION, IOWA. DENSE BRANCHING MAKES IT DESIRABLE FOR WINDBREAK PLANTING.

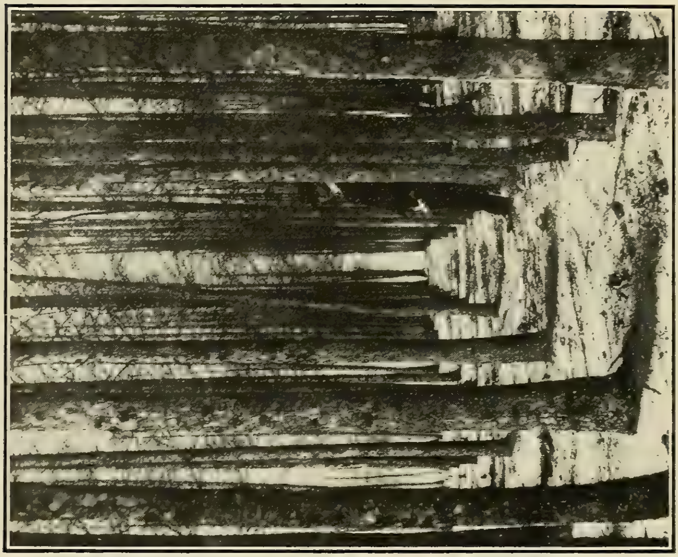


FIG. 2.—EUROPEAN LARCH PLANTATION, ILLINOIS, 27 YEARS OLD.

SILVER MAPLE (Acer saccharinum Linn.).

Silver maple is a rapid-growing tree, probably ranking next to cottonwood in this respect among the species discussed. It is also very hardy and comparatively free from serious insect or fungous attack. The tree, which reaches maturity in from 35 to 40 years, forms a rather crooked, twisted bole, and so yields very little lumber. Its chief value is for cordwood, or to insure a windbreak in a short time. Silver maple is occasionally used for posts for temporary fences, but is not durable in contact with the soil, and unless treated with a preservative, will not last more than two or three years.

Since silver maple is easily and cheaply propagated, it is a good tree to plant for the production of cordwood in the Middle Western States, and probably also in any part of the Northeast, provided the plantation is made on well-drained soils which are not subject to excessive drying out. A spacing of 6 by 8 feet is close enough.

In Table 4 $2.50 per cord has been assumed as the average stumpage value for the species.

TABLE 4.—*Yield and value of silver maple* (*Acer saccharinum*).

Age.	Location.	Soil.	Original spacing.	Present number of trees per acre.	Average diameter breast high.	Average height.	Yield per acre, cordwood (90 solid cu. ft.=1 cord =128 stacked cu. ft.).	Average value of land per acre during life of plantation.	Total amount of costs per acre to date.	Present value of products per acre (includes value of thinnings).	Profit (+) or loss (−) per acre. Total.	Profit (+) or loss (−) per acre. Annual.
Yrs.			*Ft.*		*Ins.*	*Ft.*	*Cords.*					
9	Illinois..	Black loam.........	5 x 8	1,018	4.0	36	16.2	$125.00	$42.60	$40.50	− $2.10	−$0.20
12	Iowa....	Black sandy loam...	4 x 5	1,060	4.1	41	19.8	70.00	54.92	49.50	− 5.42	− .38
18	...do....	Black loam.........	3½x 4½	979	4.4	43	(?)	60.00	50.73	(?)	....	(?)
20	...do....	.....do..............	5 x 9	376	6.2	46	20.1	60.00	58.93	50.25	− 8.68	− .32
20	...do....	.....do..............	4 x 4	530	6.1	46	29.5	60.00	70.56	72.75	+ 2.19	+ .08
26	...do....	Quite sandy loam...	3½x 7	323	7.1	51	34.7	60.00	96.54	141.39	+ 44.85	+ 1.16
[1] 27	...do....	Black loam.........	6 x 8½	267	8.3	58	31.1	50.00	76.65	422.75	+346.10	+ 8.50
34	...do....	.....do..............	8 x 8	328	6.8	53	19.0	40.00	90.14	47.50	− 42.64	− .74
34	...do....	.....do..............	3 x 5	294	8.9	60	46.9	50.00	110.53	117.25	+ 6.72	+ .13
35	...do....	Clay loam...........	8 x 14	166	10.8	55	36.7	50.00	112.90	91.75	− 21.15	− .35
35	...do....	Black loam.........	4 x 7	274	8.1	74	38.0	40.00	90.58	95.00	+ 4.42	+ .19
35	...do....	.....do..............	6 x 8	177	10.4	52	32.8	50.00	118.92	82.00	− 36.92	− .61
35	...do....	.....do..............	7½x 7½	240	11.8	71	91.8	50.00	118.92	229.50	+110.58	+ 1.83
40	...do....	Black sandy loam...	8 x 8	298	8.5	66	40.4	50.00	144.68	101.00	− 43.68	− .58

EUROPEAN LARCH (Larix europaea deC.).

European larch has been planted quite extensively in Illinois and Iowa, and to some extent in Rhode Island, Connecticut, and Massachusetts. Results, however, do not bear out the claims made for it (see Table 5). This is in part because plantations in this country have not been made in situations similar to the native habitat of the species which is in the higher, cooler altitudes; the trees have not always been properly spaced, and the cost of planting stock has often been excessive (in one case $51 per thousand and in several

[1] The complete record kept of the amount of cordwood cut each year accounts for the large value of the products for this plantation.

others $20). Probably the most important reason for the poor returns, however, has been the lack of market for European larch telephone or telegraph poles, claimed to be the most valuable form of product. For this reason the owners have been unable to realize any profit from their plantations. In one instance in Iowa the owner secured from a local farmer's telephone company $1 each for poles 6 inches in diameter at the butt and 20 feet long, and $1.50 for slightly larger ones. As a rule, however, there is no demand for the poles, and lumber dealers do not handle them. They are considered as no more durable than white cedar poles, are much heavier than the latter, and the wood is so hard that it is difficult for a lineman to force his climbing irons into it. The values assumed for European larch poles are much less than those ordinarily received for similar-sized poles of other species: 15-foot poles, 20 cents; 20-foot, 30 cents; 25-foot, 50 cents; 30-foot, 75 cents; 35-foot, $1.25; 40-foot, $2; 45-foot, $3; and 50-foot, $4.50. First-class posts 4 to 6 inches in diameter at the small end and 7 feet long have been valued at 10 cents each, and cordwood at $1 per cord of 90 solid cubic feet.

European larch is exceedingly intolerant; closely spaced stands rapidly thin themselves, and thus do not fully utilized the ground. It seems advisable, therefore, to use a wide spacing of 10 by 10 or 12 by 12 feet, and fill in with some tolerant, slightly more slowly growing species, such as white pine, white spruce, or red oak. This wider spacing is especially desirable, since larch stock is expensive and the initial cost may be considerably reduced by filling in with a cheaper species. Larch requires a fresh, well-drained, moderately heavy soil. It does not do well in light, very sandy soils, or in very poorly drained, heavier ones,

It is not advisable to plant European larch in the New England States, because old plantations are now beginning to be attacked by the sawfly. In the Middle West it is questionable whether European larch would be as profitable if planted on the good soils (on which the present plantations stand) as some other species. It does not grow as rapidly as certain hardwoods which furnish fully as good post material, and it lacks their capacity to send up sprouts. Nothing excells it, however, in producing straight timber, and a few larch trees trees should be planted on every farm in the Middle West, in order to produce sticks for hay poles, braces, beams, scantlings, or other general utility purposes. Larch starts growth very early in the spring, and it is difficult to get stock for planting at that time which has not already started growth in the nursery.

TABLE 5.—*Yield and value of European larch* (*Larix europaea*).

Age.	Location.	Soil.	Original spacing.	Present number of trees per acre.	Average diameter breast high.	Average height.	Yield per acre. Poles (all sizes).	Yield per acre. Posts.	Yield per acre. Cordwood[1] (90 solid cu. ft.=1 cord = 128 stacked cu. ft).	Average value of land per acre during life of plantation.	Total amount of costs per acre to date.	Present value of products per acre (includes value of thinnings).	Profit (+) or loss (−) per acre. Total.	Profit (+) or loss (−) per acre. Annual.
Yrs.			*Ft.*		*Ins.*	*Ft.*	*No.*	*No.*	*Cords.*					
18	Iowa..	Sandy loam....	4 x 4	923	4.9	27	....	336	13.73	$65.00	$97.58	$47.33	−$50.25	−$2.15
27	...do...	Black loam.....	4 x 4	506	7.2	46	296	299	11.74	60.00	143.35	146.04	+ 2.69	+ .06
28	...do...	.....do.........	3½ x 6	1,107	3.7	40	110	....	15.56	30.00	104.83	43.46	− 61.37	− 1.43
28	Conn..	Loam...........	4 x 4	1,120	4.3	35	....	110	19.69	35.00	206.31	30.79	−175.52	− 4.09
28	Iowa..	Black loam.....	10 x 12	189	9.2	43	180	132	1.89	65.00	117.15	65.79	− 51.36	− 1.20
28	...do...	.....do.........	8 x 8	487	7.6	47	363	92	10.41	65.00	132.27	164.31	+ 32.04	+ .75
31	...do...	Clay loam......	4 x 5	526	7.6	57	351	429	10.48	60.00	147.12	226.03	+ 78.91	+ 1.58
33	Conn..	Loam...........	4 x 6	380	6.4	70	330	240	9.35	14.00	172.05	289.85	+117.80	+ 2.14
33	Mass..	.....do.........	(?)	212	6.5	53	124	32	4.94	15.00	171.45	56.34	−115.11	− 2.09
35	...do...	White sand....	4 x 4	527	6.6	43	219	140	12.48	15.00	49.23	111.88	+ 62.65	+ 1.03
35	...do...	.....do.........	4 x 4	1,324	4.5	29	27	216	20.97	15.00	49.23	47.97	− 1.26	− .02
35	Iowa..	Black loam.....	8 x 8	221	10.0	57	214	170	3.97	50.00	131.57	172.42	+ 40.85	+ .67
35	...do...	.....do.........	7½ x 7½	192	11.2	57	191	155	3.00	50.00	133.68	205.05	+ 71.37	+ 1.18
35	...do...	.....do.........	4 x 6	498	7.4	44	325	305	10.33	60.00	163.02	157.58	− 5.44	− .09
35	...do...	Clay loam......	3 x 7	475	7.4	68	466	308	10.72	25.00	112.20	275.42	+163.22	+ 4.35
37	...do...	Black loam.....	4 x 4	330	8.9	57	308	330	6.26	50.00	194.41	252.46	+ 58.05	+ .88
39	Ill.....	.....do.........	(?)	571	7.7	54	391	462	12.10	80.00	272.59	214.50	− 58.09	− .80
39	Iowa..	Black sandy loam.	3½ x 3½	522	7.0	53	378	269	12.91	60.00	235.15	150.51	− 84.64	− 1.17
40	...do...	Black loam.....	4 x 4	398	8.3	52	342	193	7.44	30.00	160.78	212.04	+ 51.26	+ .68
41	...do...	.....do.........	4 x 4	299	9.4	45	274	429	10.48	30.00	147.12	226.03	+ 78.91	+ 1.58
41	...do...	Black sandy loam.	8 x 8	292	8.3	64	285	435	6.51	40.00	137.28	223.01	+ 85.73	+ 1.09
50	Mass..	White sand....	6 x 6	316	7.3	49	264	71	6.71	10.00	84.36	103.61	+ 19.25	+ .17
60	...do...	Clay loam......	6 x 6	155	9.7	62	153	162	2.96	10.00	117.58	110.06	− 7.52	− .05
[2] 28	Iowa..	Black loam.....	5	1,000	10.6	50	608	340	5.81	65.00	115.32	189.92	+ 74.60	+ 1.74

[1] In addition to the poles and posts shown in preceding columns.
[2] Single row reckoned as 25 feet wide by 1,742 feet long = 1 acre.

SCOTCH PINE (Pinus sylvestris Linn.).

Scotch pine will grow in all sections of the eastern United States, and is well adapted for sandy soils too poor for agriculture or even for the growth of white pine. The tree seems to do equally well on the poor, sandy, Norway pine lands of Michigan and on old worn-out lands of New England. For the first 15 or 20 years Scotch pine makes very rapid height growth, often from 20 to 30 inches a year.

Because of its hardiness and freedom from disease, it is to be regretted that the Scotch pine already planted consists largely of a variety from central Germany, the trees of which, when about 20 years old, become crooked, irregular, ragged, and of very poor timber form, yielding only one or two logs per tree. In Europe, on the other hand, trees grown from seed collected in the Scotch pine forests of the Baltic provinces of Russia, ordinarily called the Riga variety, have straight, cylindrical, well-developed trunks, and yield wood of a higher quality than the Scotch pine of central Germany. Unless, therefore, the Riga variety can be secured, the planting of Scotch pine is not recommended.

The tree is decidedly intolerant, and a rather wide spacing, 6 by 8 or 8 by 8 feet, is advisable, or it may be planted in mixture with white pine on soils adapted to both species. In the latter case a spacing of 6 by 6 feet, with the two species alternating, will probably give the best results.

Stumpage values for Scotch pine in the Middle Western States are placed at $8 per thousand board feet for lumber and $2 per cord for cordwood.

TABLE 6.—*Yield and value of Scotch pine* (*Pinus sylvestris*).

Age.	Location.	Soil.	Original spacing.	Present number of trees per acre.	Average diameter breast high.	Average height.	Yield per acre.		Av. value of land per acre during life of plantation.	Total amount of costs per acre to date.	Present value of products per acre (includes value of thinnings).	Profit (+) or loss (−) per acre.	
							Timber.	Cordwood[1] (90 solid cu. ft.=1 cord=128 stacked cu. ft.).				Total.	Annual.
Yrs.			*Ft.*		*Ins.*	*Ft.*	*Bd.ft.*	*Cords.*					
37	Iowa..	Black loam.	4 x 4	884	6.4	49	2,478	60.00	$40.00	$127.67	$139.82	+$12.15	+$0.18
39	...do...	...do........	4 x 8	497	8.4	44	6,971	31.11	50.00	179.58	117.99	− 61.59	− .85
40	...do...	...do........	8 x11	362	9.6	44	7,943	24.43	50.00	183.80	112.40	− 71.40	− .95
41	Ill.....	...do........	7 x16½	375	8.5	41	5,781	26.74	80.00	233.72	99.73	−133.99	− 1.70
40–50	Mass..	Poor sand...	6 x 6	521	6.8	29	......	......	10.00	....	....	....	......

[1] In addition to the board feet shown in preceding column.

WHITE PINE (Pinus strobus Linn.).

White pine seems well suited to the climate of the whole eastern portion of the country from New England to Iowa. It is not particularly exacting as to soil, but requires good drainage. It flourishes on the worn-out pasture lands of New England, on the almost pure sands of Cape Cod, and on the good agricultural soils of the Middle West. It will also undoubtedly thrive on some of the poor, sandy farm lands of the Indiana and Ohio region.

White pine is fairly tolerant, and in order to secure a clear bole very close spacing, 4 by 4 feet or 4 by 6 feet, is necessary. In practice, however, a spacing of 6 by 8 feet to 8 by 8 feet is usually close enough. In a stand 50 years old, spaced 6 by 8 feet, the branches die to a height of 40 to 50 feet, and though they persist, the knots are usually sound and the timber of fairly good quality. In a three-row windbreak in eastern Iowa, 52 years old and spaced 6 by 7 feet, the owner cuts timber which, although somewhat knotty, sells as lumber for from $36 to $38 per thousand feet board measure. White pine is recommended for windbreak planting in the Middle West, since it is an excellent tree for the purpose and produces a large amount of timber of good quality.

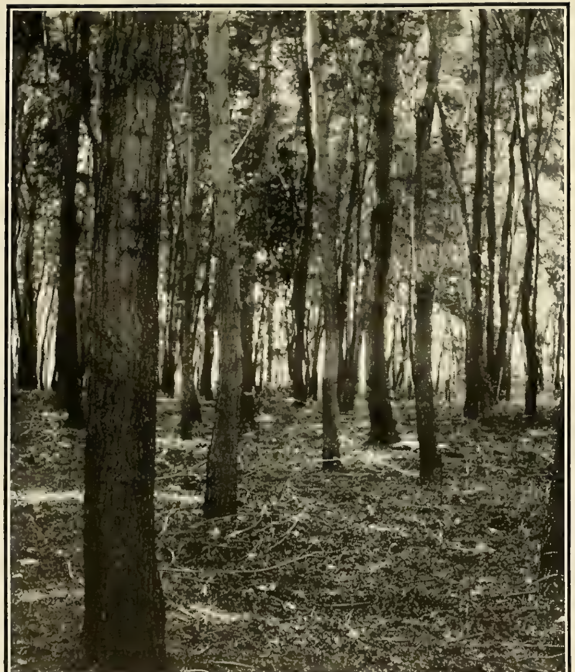


FIG. 1.—SILVER MAPLE GROVE, IOWA, SHOWING GOOD FOREST FLOOR CONDITIONS AND RATHER TYPICAL CROOKED GROWTH OF THE SPECIES IN THIS REGION.

FIG. 2.—NORWAY AND WHITE PINE IN MIXTURE, NORTHEASTERN IOWA, 43 YEARS OLD. ORIGINAL SPACING 1 BY 6 FEET.

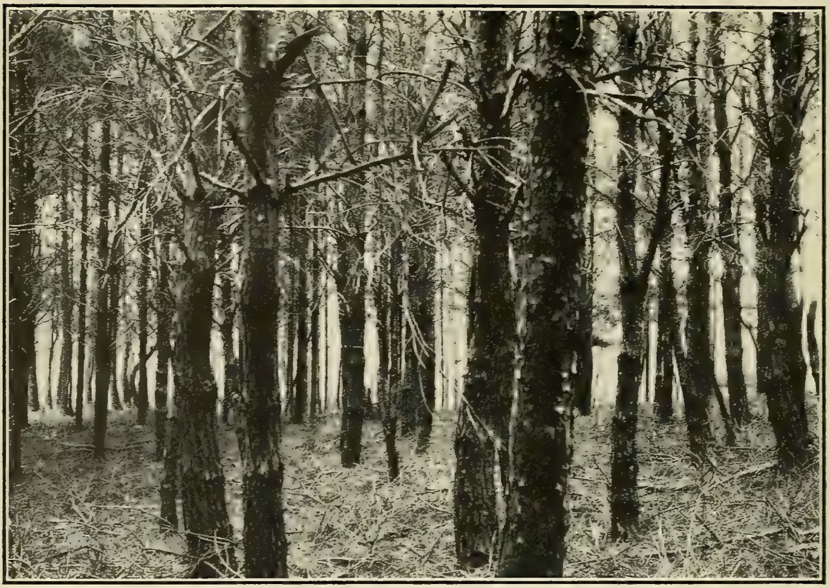


FIG. 1.—SCOTCH PINE PLANTATION, CAPE COD, MASS., 35 YEARS OLD, ON VERY SANDY SOIL.

FIG. 2.—TWENTY-THREE-YEAR-OLD PLANTATION, IOWA. SCOTCH PINE ON RIGHT, WHITE PINE ON LEFT. SHOWS CHARACTERISTIC APPEARANCE OF SCOTCH PINE IN THIS REGION AFTER AGE OF 20 YEARS.

Where white pine grows well there is no object in planting it in mixture with other species. In certain regions, however, particularly in New England, the tree is subject to attack by the white pine weevil (*Pissodes strobi* Peck), which kills the top of the leading shoot through a year or two of its growth. A new leader is ordinarily formed by one of the side shoots, which in turn is subject to attack. The result is a crooked, unsightly tree, whose value for timber is considerably impaired, especially in stands grown on a short rotation, when there is not sufficient time for the crooks to be covered through growth of the bole. Wherever the weevil has appeared it would be better to plant Norway pine with the white pine than to plant the latter species alone. Young Norway pine grows as rapidly in height as the white, and though its lumber is less valuable, it is less subject to attack by the weevil.

In Table 7 the white pine plantations listed are all in the Middle West. Similar figures for New England plantations appear in other publications of the Forest Service and of various New England States. For the Middle West white pine stumpage has been given a value of $10 per thousand feet for stands with an average diameter under 11 inches, and of $12 for stands 11 inches and over, both of which are very conservative. White pine is usually cut by small portable sawmills, and the felling and sawing together do not cost more than $12 per thousand feet board measure for lumber which brings from $36 to $38 per thousand.

TABLE 7.—*Yield and value of white pine (Pinus strobus).*

Age.	Location.	Soil.	Original spacing.	Present number of trees per acre.	Average diameter breast high.	Average height.	Yield per acre in timber.	Average value of land per acre during life of plantation.	Total amount of costs per acre to date.	Present value of products per acre (includes value of thinnings).	Profit (+) or loss (−) per acre. Total.	Profit (+) or loss (−) per acre. Annual.
Yrs.			*Ft.*		*Ins.*	*Ft.*	*Bd. ft.*					
21	Iowa..	Black loam...........	11 x 14	215	8.7	39	4,760	$80.00	$68.31	$57.60	−$10.71	−$0.72
23	...do..	Clay loam.............	6 x 8	409	7.3	39	4,273	30.00	48.23	62.73	− 14.50	− .17
35	...do..	.....do..............	6 x 7	391	8.8	52	12,031	25.00	75.67	120.31	+ 44.64	+ .74
37	...do..	Black loam...........	8 x 9	549	9.7	50	22,513	40.00	113.96	225.13	+111.17	+ 1.68
39	Ill....	.....do..............	(?)	371	8.5	39	7,380	80.00	272.59	73.90	−198.69	− 2.75
39	Iowa..	Black sandy loam.....	4 x 4	788	8.1	47	16,136	40.00	173.73	201.36	+ 27.63	+ .38
[1] 41	...do..	Black loam...........	8 x 8	408	[2] 9.4 / [3] 10.1	62 / 64	16,748	30.00	113.00	260.81	+147.81	+ 1.89
42	...do..	.....do..............	1 x 6½	850	7.5	53	15,206	30.00	107.73	152.06	+ 44.33	+ .54
42	...do..	.....do..............	16 x 16	158	12.3	60	13,175	30.00	98.21	158.10	+ 59.89	+ .73
52	...do..	.....do..............	6 x 7	374	11.1	59	26,400	20.00	137.59	316.80	+179.21	+ 1.47
[4] 48	...do..	.....do..............	4	560	16.0	60	86,640	30.00	127.93	346.56	+218.63	+ 2.09
[4] 52	...do..	.....do..............	6	435	14.1	59	50,500	30.00	108.58	202.00	+ 93.42	+ .77

[1] Mixture of white pine and European larch. Larch products are included in the returns.
[2] Pine.
[3] Larch.
[4] Single rows reckoned as 25 feet wide by 1,742 feet long=1 acre.

NORWAY SPRUCE (Picea excelsa Link).

Norway spruce has not been planted very extensively anywhere in the eastern United States. Because of its compact crown, especially when young, and the tenacity of its lower branches, this species has found favor in the Middle West for windbreaks of one to three or four rows. It will probably increase in favor. The tree prefers a fresh, well-drained, loamy soil, but in New England has succeeded fairly well on a sandy one. A young plantation on very sandy land in central Michigan, however, while still alive, is making a height growth of only 2 or 3 inches a year, while Scotch pine on a similar site is growing at the rate of from 6 inches to 2 feet a year.

Norway spruce is decidedly tolerant, and to obtain timber of the best form it should be spaced as closely as 5 by 5 feet to 6 by 6 feet. For windbreak purposes, however, the spacing should be not less than 12 by 12 feet, in order to insure that the lower branches will remain alive and bear foliage. Timber from such trees, while not clear, is of fair quality, and has been used in the Middle West for farm buildings. Norway spruce is also suitable for underplanting old groves of trees with naturally open crown covers, such as black walnut or cottonwood, and stands becoming open through deterioration. The species grows nearly as fast as white pine, and on loamy soils would probably be a good tree to plant in mixture with the latter. It appears to be hardy as far west as central Iowa, but west of that it is ragged and scrubby when mature, at the age of about 40 years. Some nurserymen attribute this to the severe winds in that region; though the extremely high summer temperatures and low humidities may have something to do with it, since spruce is naturally a tree of relatively cool regions with high humidities. Where exposed to severe winds, as on the New England coast, the tree is likely to be broken off or its top bent.

For the Middle West, Norway spruce has been assigned a stumpage value of $9 for lumber and $2.50 for cordwood, and for the northeast region $5 for lumber and $1 for cordwood.

BLACK WALNUT (Juglans nigra Linn.).

Black walnut does well throughout the central hardwood region, and as far west as the Missouri River. It is a hardy tree, and though seldom planted in the Eastern States there is no reason why it should not succeed there. For its best development, however, the tree requires deep clay or sandy loam soils, which, of course, are also excellent for agriculture. For this reason alone it is not likely to be planted to any great extent.

Black walnut is easily propagated by planting the nuts in the fall on the permanent site. The tree is decidedly intolerant, and sheds its lower branches readily even with a relatively wide spacing. One

of 6 by 8 feet or 8 by 8 feet is close enough. The older trees, however, have open crowns, and should be underplanted as soon as they cease to cast shade enough to prevent a growth of grass on the forest floor. For such underplanting, white pine, white or Norway spruce, or red oak, should prove satisfactory.

Black walnut does not grow very rapidly, and takes from 60 to 100 years to produce the best timber. In general, it is not a particularly good tree for private owners to plant.

The only value given to black walnut in plantations has been $4 per cord on the stump. (See Table 8.) This is undoubtedly too high for cordwood alone, but since much of the material can be used for braces or small poles, the valuation is probably a fair one.

TABLE 8.—*Yield and value of black walnut (Juglans nigra).*

Age.	Location.	Soil.	Original spacing.	Present number of trees per acre.	Average diameter, breast high.	Average height.	Yield per acre, cordwood (90 solid cu. ft.=1 cord=128 stacked cu. ft.).	Average value of land per acre during life of plantation.	Total amount of costs per acre to date.	Present value of products per acre (includes value of thinnings).	Profit (+) or loss (−) per acre. Total.	Profit (+) or loss (−) per acre. Annual.
Yrs.			*Feet.*		*Ins.*	*Ft.*	*Cords.*					
12	Indiana.	Black sandy loam..	4½ x 6	512	3.8	27	7.5	$70.00	$39.97	$30.00	−$9.97	−$0.70
25	Iowa....	Black loam.........	8 x 8	359	6.3	42	14.8	60.00	79.77	59.20	−20.57	− .56
28	...do.....	.....do...............	8 x 8	548	5.5	42	17.9	60.00	91.67	71.60	−20.07	− .47
28	...do.....	.....do...............	1½ x 7	708	4.1	26	8.6	60.00	97.16	34.40	−62.76	− 1.46
28	...do.....	Black sandy loam..	4 x 4	342	7.0	41	20.0	60.00	96.02	80.00	−16.02	− .37
31	...do.....	Black loam.........	4 x 5	492	7.0	51	34.6	50.00	93.12	138.40	+45.28	+ .91
32	...do.....	.....do...............	5 x 13	239	8.3	54	24.2	50.00	95.99	96.80	+ .81	+ .02
35	...do.....	Black sandy loam..	8 x 9	149	8.7	46	12.4	50.00	109.80	49.60	−60.20	− 1.00
37	...do.....	Black loam.........	8 x 8	136	7.7	44	9.1	60.00	135.81	36.40	−99.39	− 1.50
38	Illinois..	.....do...............	8 x 8	303	8.6	55	33.8	80.00	205.95	135.20	−70.75	− 1.02
40	Iowa....	.....do...............	4 x 4	321	8.3	52	31.8	40.00	114.92	127.20	+12.28	+ .16
42	...do.....	.....do...............	7 x 12	138	12.3	66	39.6	40.00	120.62	158.49	+37.87	+ .46

ASH (GREEN AND WHITE) (Fraxinus lancecolata Borkh. and Fraxinus americana Linn.).

Green ash has been planted to some extent in Iowa and Illinois, while east of these States white ash has been given preference. In the Prairie States green ash withstands more trying conditions, especially drought, than white ash, but with suitable soil conditions either species should succeed in any part of the eastern region. Both species prefer good, fresh, well-drained clay or sandy loam soil, but both also give promise of growing well on the poor, worn-out clay, or rocky clay farm soils of the central hardwood region. This fact may make them valuable trees for planting on those lands, since the lumber of mature trees has a high value and may be closely utilized for handle material. Ash, moreover, may be easily and cheaply propagated simply by sowing the seed on the permanent planting site. Ash is intolerant and sheds its lower branches well, and considering this reason alone it would seem that a rather wide spacing should be used. But on account of its habit, discussed on page 18, of com-

monly forming its leader from one of the side shoots, it seems best to use a closer spacing, 4 by 4 feet to 4 by 6 feet, in order, if possible, to correct the habit. The stand should then be thinned as soon as needed.

Green ash has come up naturally under cottonwood, and should prove a good tree for underplanting old stands of that species.

In the plantations examined ash has not grown as rapidly as in natural stands. Lack of knowledge regarding the tree's requirements is probably responsible for this, and both green and white ash should be given a further trial on various kinds of soil, though it would not pay to plant them on good agricultural land. Young green ash trees are inclined to be somewhat crooked, but the timber is strong and can be used for many purposes on a farm. A valuation of $4 per cord has been put upon cordwood (Table 9), since most of the timber so classed can in fact be put to more valuable use.

TABLE 9.—*Yield and value of green ash (Fraxinus lanceolata).*

Age.	Location	Soil.	Original spacing.	Present number of trees per acre.	Average diameter breast high.	Average height.	Yield per acre, cordwood (90 solid cu. ft.=1 cord =128 stacked cu. ft.).	Average value of land per acre during life of plantation.	Total amount of costs per acre to date.	Present value of products per acre (includes value of thinnings).	Profit (+) or loss (−) per acre. Total.	Profit (+) or loss (−) per acre. Annual.
Yrs.			*Ft.*		*Ins.*	*Ft.*	*Cords.*					
17	Iowa....	Yellow clay loam.....	Broadcast.	2,386	3.1	27	17.7	$80.00	$59.20	$70.80	+$11.60	+$0.53
20	...do.....	Black loam............	5 x 9	541	4.8	39	13.2	60.00	70.10	52.80	− 17.30	− .64
20	...do.....	.....do...............	4 x 4	679	5.0	39	21.4	60.00	72.37	85.60	+ 13.23	+ .49
26	...do.....	.....do...............	12 x 12	299	5.6	35	9.2	60.00	84.74	36.80	− 47.94	− 1.24
28	...do.....	.....do...............	6 x 6	121	8.6	49	11.5	60.00	101.74	46.00	− 55.74	− 1.30
37	...do.....	.....do...............	4 x 4	745	5.2	46	22.2	40.00	98.52	88.80	− 9.72	− .15
40	Illinois..	.....do...............	(?)	283	8.5	59	39.3	80.00	219.25	157.20	− 62.05	− .18
41	Iowa....	Quite sandy loam....	1 x 4	382	6.6	49	11.5	40.00	101.74	46.00	− 55.74	− 1.30

NORWAY PINE (Pinus resinosa Ait.).

Norway or red pine is especially adapted for planting on poor, sandy or gravelly soils which will not even support a good growth of white pine. On good loam soils in Iowa trees 40 years old have reached a height of from 50 to 55 feet and a diameter of 8 inches, while on very poor, sandy soil in Rhode Island and Massachusetts a height of 40 feet and a diameter of 8 to 10 inches have been attained in 40 years. Norway pine is decidely intolerant, and a spacing of 6 by 8 feet is close enough. Planting stock is usually rather expensive, because of the difficulty of obtaining seed, and the wide spacing has the additional advantage of reducing the planting costs.

Norway pine lumber is less valuable than white pine, and the production per acre is not so large, but the tree is very hardy and exceptionally free from disease. It is less subject to attack by the pine

BLACK WALNUT PLANTATION, INDIANA, 20 YEARS OLD.

NORWAY PINE PLANTATION, RHODE ISLAND, 33 YEARS OLD, VERY SANDY SOIL.

weevil, and therefore is preferable to white pine where there is danger from this insect, as in portions of New York and New England. It also does well when mixed with white pine.

RED OAK (*Quercus rubra* Linn.).

Largely on account of their slow rate of growth, the oaks have not been planted extensively in this country. Red oak, however, grows rather rapidly, and has much to commend it. It can be easily and cheaply propagated by planting the acorns directly on the site in the spring, after stratifying them over winter; it is hardy throughout the eastern region; it is a persistent grower after becoming established; it produces valuable material; and it is especially well fitted for growth on poor, wornout clay soils. This last fact alone makes it well worth considering. Catalpa has done poorly on some very poor, rocky, clay soils in the Middle West where red oak would doubtless have been successful. Red oak is quite tolerant, and should prove valuable for underplanting old, deteriorating stands on poor soils; also for planting in mixture with more rapid growing, intolerant trees such as European larch, or with equally rapid growing tolerant trees such as white pine. When planted pure, it should be spaced about 6 by 6 feet. A Rhode Island plantation on poor sandy soil has reached an average diameter of 9 inches and a height of 45 feet in 34 years; another plantation on good black agricultural soil in Illinois has reached an average diameter of 5 inches and a height of 38 feet in 25 years.

HARDY CATALPA (*Catalpa speciosa* Warder).

In gathering data for this report very little attention was given hardy catalpa plantations, because the tree has been considered in previous publications. Hardy catalpa requires for its best development a fresh, well-drained loamy soil, or a sandy river-bottom soil, where the water table is within a few feet of the surface. A spacing of from 6 by 6 feet to 6 by 8 feet is close enough. The tree grows rapidly and sprouts vigorously from the stump, thus insuring several crops from one planting. It needs cultivation and pruning, and produces material chiefly valuable for its durability in contact with the ground. The species is hardy in the Middle West as far north as central Iowa, and in Michigan near the lake shore as far north as 43° latitude. In the interior of Michigan, however, it is frozen back at this latitude. Although not yet planted extensively in New England, some young plantations in Connecticut and Rhode Island indicate that it will do well there, unless planted on the most exposed sites. On good soils in the Middle West plantations have reached a diameter of from 6 to 7 inches and a height of from 40 to 50 feet in 20 years.

Hardy catalpa gives promise of growing well on some of the poorer wornout clay soils of the Middle West, but with our present knowledge

of the tree's requirements it can not yet be recommended for such sites. It is also growing on sandy upland soil in Rhode Island, but has not attained a large size there. Much catalpa has been planted under circumstances which practically insure financial loss. Agents have exaggerated the good qualities of the species, and have sold a large amount of stock at $20 to $25 per thousand, advising that it be planted on almost any soil, good or poor, which happened to be available. Prospective planters should consult their State forestry officials or the United States Forest Service.

BLACK LOCUST (Robinia pseudacacia Linn.).

Were it not for the locust borer, black locust could be recommended as one of the best trees for forest planting throughout most of the eastern region. It grows well on poor, sandy, gravelly, or clay soils, sprouts vigorously, and is hardy as far north as southern Michigan, but farther north is killed back in winter. One exceptionally good plantation in Indiana has reached a diameter of 7 inches and a height of 45 feet in 13 years. The wood is very durable in contact with the ground, and makes valuable fence posts. But on account of the likelihood of destructive attacks by the locust borer the planting of black locust for commercial purposes can not be recommended. Some plantations, it is true, have not been attacked by the insect; some localities are at present free from it; but plantations from Kansas to New England have been seriously injured, and to set out black locust to-day for commercial purposes would be a very doubtful venture.

OTHER SPECIES.

Certain other species promise well for the eastern region, although they have not all been tested to the age of maturity. Young plantations of western yellow pine are growing well on poor, rocky clay agricultural lands in Ohio and southern Michigan, and on dry, deep, sandy lands in New York, and there seems to be no reason why the species should not do fully as well in New England on similar soils. It is quite hardy and resistant to drought.

Chestnut would be an excellent tree to plant, particularly in southern New England, Pennsylvania, and parts of New York and Ohio, were it not for the very virulent fungus, *Endothia parasitica* (Murrill) Anderson, which has killed a great many trees and threatens to destroy most of the remaining stands. No practical method of combating this disease has been devised, so it is not advisable at present to start plantations of chestnut.

Yellow poplar should do well in the eastern region on moist hillsides with good, well-drained soils, or along the banks of streams. It produces valuable timber, commands a high stumpage price, and makes fairly rapid growth.

Douglas fir has been planted on poor stony soils in southern Michigan and Ohio and on poor sandy soils in Rhode Island, and so far has done very well. It is hardy and grows fairly rapidly. The Rocky Mountain or northern Idaho variety should prove to be an admirable tree for planting in the eastern region, but the Pacific Coast variety may be damaged by frost.

White spruce has lately come into favor in the Middle West as a tree for windbreaks, and would probably do as well in the northeast. It does not grow as rapidly as Norway spruce, but retains its lower foliage better, and at the age of about 40 years, when Norway spruce is likely to become ragged, is in its best condition for windbreak purposes. For this purpose it should not be spaced more closely than 12 by 12 feet. On account of its tolerance, it is well adapted for underplanting old deteriorating stands of cottonwood or maple.

TABLE 10.—*Species and methods for planting in different regions.*

Species to plant.	Soil.	Spacing.	Planting method.	Products.	Age.
TREELESS REGION.					
					Years.
Cottonwood	Moist soil; sandy river bottom best.	15 x 15 and underplant with silver maple, or plant 2 to 4 feet apart in rows.	Plant cuttings in a furrow.	Lumber and cordwood.	30–40
Silver maple	Fresh to moist loam or sandy loam.	6 x 8	Sow seed direct	Cordwood	25–40
Green ash	Well-drained loam soil.	4 x 4	Sow seed direct or slit method.	Handle material, farm timbers.	40–50
Hardy catalpa	Well-drained loam or sandy loam.	6 x 8	Slit method	Posts	18–20
Black walnut	do	6 x 6	Sow seed direct	Lumber	50–75
European larch	do	12 x 12; fill in to a 6 x 6 spacing with white pine.	Slit method	Poles, posts	25–40
White pine	Well-drained sandy or loam soils.	6 x 6	Slit or furrow method.	Lumber	50
White spruce	Fresh to moist loam.	For windbreak 10 x 10.	do	Lumber, pulp, cordwood.	60
Norway spruce	do	do	Slit method	do	50
HARDWOOD REGION.					
Black walnut	Well-drained black or clay loam.	6 x 6	Sow seed direct	Lumber, pulp, cordwood.	50–75
White ash	do	4 x 4	Sow seed direct or slit method.	Handle material, farm timbers.	40–50
Green ash	do	4 x 4	do	do	40–50
Hardy catalpa	do	6 x 8	Slit method	Posts	18–20
Tulip poplar	Moist loam	8 x 8	do	Lumber	40–50
White pine	Sandy soil or gravelly loam.	6 x 6	do	do	50
Red oak	do	6 x 6	Sow seed direct	do	50
NORTHEAST REGION.					
White pine	Sandy or gravelly loam; rocky hillsides.	6 x 6	Sow seed direct; dig hole for each tree; slit method.	Lumber	50
Norway pine	Poor sandy or gravelly soils.	6 x 8	do	do	50–60
Norway spruce	Heavier loam soils.	5 x 5 to 6 x 6	Slit method; dig hole for each tree.	do	50–60
Red oak	Sandy or clay soils.	6 x 6	Sow seed direct	do	50
Yellow poplar [1]	Moist loam soil	8 x 8	Slit method	do	40–50

[1] Yellow poplar should not be planted farther north than southern New York or southern New England.

APPENDIX.

Below are given the prices quoted for planting stock by certain nurserymen. Prices, of course, vary somewhat from year to year. Where large lots of seedlings or transplants are desired, the planter can usually secure much lower quotations by contracting for the whole lot with a reliable nursery. A list of dealers handling different species of forest trees may be obtained from the Forest Service upon request.

Prices quoted for nursery stock by nurserymen.

Variety.	Price per thousand.			
	1-year seedlings.	2-year seedlings.	3-year transplants.	Cuttings.
Silver maple	\$3.00–\$6.00			
Red oak	3.00– 7.00			
Black locust	2.00– 3.00			
White elm	2.00– 5.00			
Honey locust	2.50– 7.00			
Cottonwood	2.50– 5.00			\$3.00
Hardy catalpa	3.00– 7.00			
Russian mulberry	3.00– 4.00			
White ash	2.50– 5.00			
White willow				\$2.00–4.00
Black walnut	8.00–10.00			
Osage orange	2.00– 4.00			
Green ash	3.00– 5.00			
Yellow poplar	6.00			
Jack pine		\$3.00	\$6.00–\$10.00	
Norway or red pine			6.00– 12.00	
Norway spruce		3.00	6.00– 12.00	
White pine		3.00	5.00– 10.00	
Scotch pine		\$3.00–4.00	5.00– 10.00	
European larch		3.00–6.00	6.00	
Western yellow pine		3.50–4.00	7.00– 12.00	

The following is a list of State forest officers, who will be glad to give advice and assistance in matters relating to forestry or forest fires to those living within their respective States.

State.	Officer in charge.	Address.
Alabama	Secretary, commission of forestry	Montgomery.
California	State forester	Sacramento.
Colorado	do	Fort Collins.
Connecticut	do	New Haven.
Delaware	State board of forestry[1]	
Georgia	Professor of forestry, Georgia State forest school	Athens.
Hawaii	Superintendent of forestry	Honolulu.
Idaho	State land commissioner[2]	Boise.
Indiana	Secretary, State board of forestry	Indianapolis.
Iowa	State forestry commissioner	Des Moines.
Kansas	State forester	Manhattan.
Kentucky	do	Frankfort.
Louisiana	President, State conservation commission	New Orleans.
Maine	State forest commissioner[2]	Augusta.
Maryland	State forester	Baltimore.
Massachusetts	do	Boston.
Michigan	do	Lansing.
Do	Forest fire warden[2]	Do.
Minnesota	State forester	St. Paul.
Montana	do	Helena.
New Hampshire	do	Concord.
New Jersey	do	Trenton.

[1] Authorized by law but not yet organized. [2] Forest fires only.

State.	Officer in charge.	Address.
New York	Superintendent of State forests	Albany.
North Carolina	Forester of State geological and economic survey	Chapel Hill.
North Dakota	State forester	Bottineau.
Ohio	do	Wooster.
Oregon	do	Salem.
Pennsylvania	Commissioner of forestry	Harrisburg.
Rhode Island	do	Chepachet.
South Dakota	Forester of the commission of school and public lands	Custer.
Tennessee	State warden of game, fish, and forestry	Nashville.
Do	Forester of State geological survey	Do.
Vermont	State forester	Burlington.
Virginia	Commissioner of agriculture	Richmond.
Do	State forester [1]	Charlottesville.
Washington	State forester and fire warden	Olympia.
West Virginia	Forest, game, and fish warden [2]	Belington.
Wisconsin	State forester	Madison.

[1] Authorized by law but not organized. [2] Forest fires only.

The following publications of the Department of Agriculture deal with forest planting. Application for any of them should be made to the Division of Publications, Department of Agriculture.

FOREST SERVICE BULLETINS.

No.
37. The Hardy Catalpa.
42. The Woodlot: Handbook for Owners of Woodlands in Southern New England.
65. Advice for Forest Planters in Oklahoma and Adjacent Regions.
76. How to Grow and Plant Conifers in the Northeastern States.
86. Windbreaks: Their Influence and Value.
121. Reforestation on the Sandhills of Nebraska and Kansas.

FOREST SERVICE CIRCULARS.

37. Forest Planting in the Sandhill Region of Nebraska.
41. Forest Planting on Coal Lands in Western Pennsylvania.
45. Forest Planting in Eastern Nebraska.
54. How to Cultivate and Care for Forest Plantations on Semiarid Plains.
55. How to Pack and Ship Young Trees.
56. Bur Oak (*Quercus macrocarpa*).
57. Jack Pine (*Pinus divaricata*).
60. Red Pine (*Pinus resinosa*).
62. Shagbark Hickory (*Hicoria ovata*).
64. Black Locust (*Robinia pseudacacia*).
65. Norway Spruce (*Picea excelsa*).
67. White Pine (*Pinus strobus*).
68. Scotch Pine (*Pinus sylvestris*).
72. Western Yellow Pine (*Pinus ponderosa*).
73. Red Cedar (*Juniperus virginiana*).
74. Honey Locust (*Gleditsia triacanthos*).
75. Hackberry (*Celtis occidentalis*).
81. Forest Planting in Illinois.
83. Russian Mulberry (*Morus alba tartarinae*).
84. White ash (*Fraxinus americana*).
85. Slippery Elm (*Ulmus pubescens*).
86. Boxelder (*Acer negundo*).
87. White Willow (*Salix alba*).
88. Black Walnut (*Juglans nigra*).
90. Osage Orange (*Toxylon pomiferum*).
91. Coffeetree (*Gymnocladus dioicus*).

No.

92. Green Ash (*Fraxinus lanceolata*).
93. Yellow poplar (*Liriodendron tulipifera*).
95. Sugar Maple (*Acer saccharum*).
106. White Oak (*Quercus alba*).
145. Forest Planting on the Northern Prairies.
154. Native and Planted Timber of Iowa.
161. Forest Planting in Western Kansas.
182. Shortleaf Pine (*Pinus echinata*).
183. Loblolly Pine (*Pinus taeda*).
195. Forest Planting in Northeastern and Lake States.

BULLETINS OF THE DEPARTMENT OF AGRICULTURE.

11. Forest Management of Loblolly Pine in Delaware, Maryland, and Virginia.
13. White Pine under Forest Management.
24. Cottonwood in the Mississippi Valley.

FARMERS' BULLETIN OF THE DEPARTMENT OF AGRICULTURE.

622. Basket Willow Culture.

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BULLETIN OF THE U.S. DEPARTMENT OF AGRICULTURE

No. 154

Contribution from the Forest Service, Henry S. Graves, Forester.
January 14, 1915.

THE LIFE HISTORY OF LODGEPOLE PINE IN THE ROCKY MOUNTAINS.

By D. T. Mason, *Assistant District Forester, District 1.*

GEOGRAPHIC DISTRIBUTION AND ALTITUDINAL RANGE.

Lodgepole pine (*Pinus contorta* Loudon) is one of the most widely distributed western conifers. Its botanical range, shown in figure 1, extends from the Yukon Territory southward through the Cascade, Sierra Nevada, and San Jacinto Mountains to northern Lower California, and through the main range of the Rocky Mountains to northern New Mexico. Its commercial range, however, is much more restricted. At present lodgepole is being lumbered extensively only in Montana, Wyoming, Colorado, and the Uinta Mountains in northeastern Utah. Large areas also occur in Idaho, Washington, Oregon, and California, but in these regions the tree is rendered less important commercially by the presence of other and more valuable timber trees.

The "lodgepole region"—that in which lodgepole is the preeminently important species—is mountainous, frequently interrupted by broad, open valleys, or plains, partly fertile and devoted to farming, and in part suitable only for grazing. The forests, as a rule, are confined to the mountains.

The altitudinal range of lodgepole pine in the Rocky Mountains decreases from south to north. In Colorado and southern Wyoming the tree is found at altitudes ranging from 7,000 feet to timber line, or 11,500 feet; in northern Wyoming at from 6,000 to 10,500 feet; and in southwestern and central Montana at from 4,500 to 9,000 feet. As a rule, however, it forms commercial stands only within an altitudinal belt from 2,000 to 2,500 feet in width. In Colorado the best stands are usually between 7,500 and 9,500 feet; in Wyoming between 7,000 and 9,000 feet; and in southwestern and central Montana between 6,000 and 8,500 feet. In the more humid northwestern portion of Montana, outside of the main lodgepole region, the species grows at

an altitude as low as 1,800 feet, and occurs as a temporary type following fire with little regard to elevation.

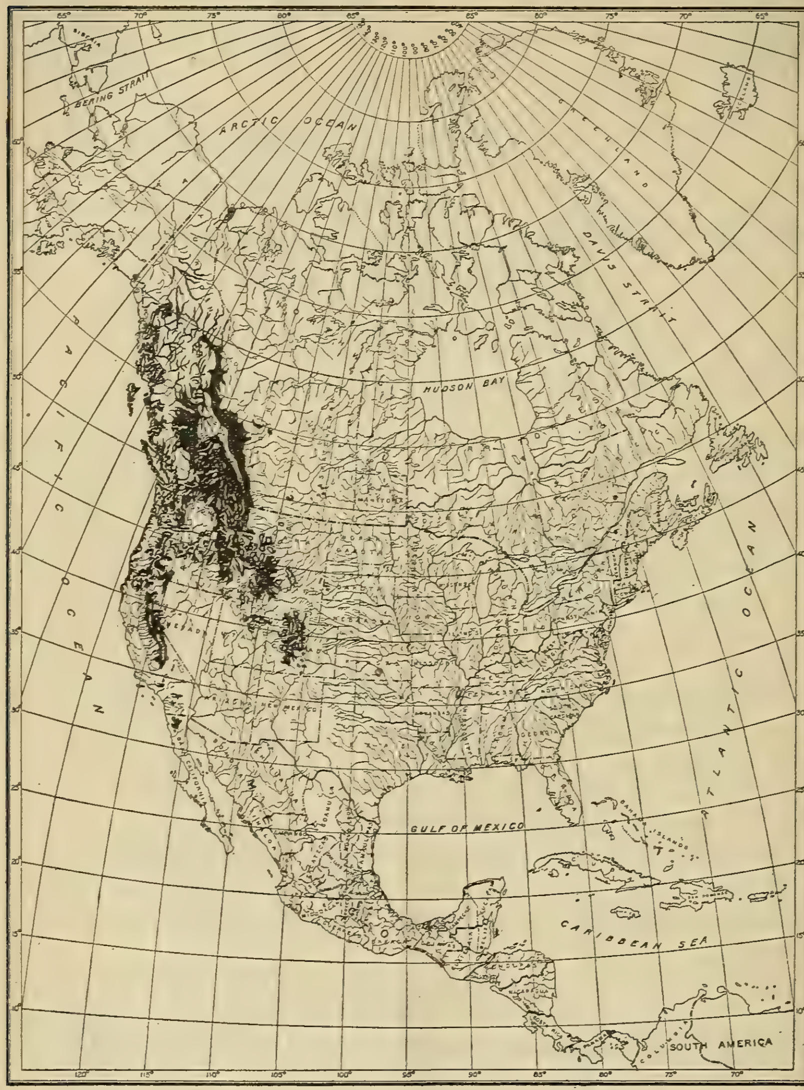


FIG. 1.—Botanical distribution of lodgepole pine.

SIZE, AGE, AND HABIT.

Lodgepole is one of the smallest of the commercially important pines. In well-developed stands approximately 140 years old, at which age the tree may be considered mature, most of the merchant-

able trees are from 8 to 14 inches in diameter breasthigh, and from 60 to 80 feet in height. However, trees up to 20 inches in diameter and 85 feet in height are common. The largest lodgepole of record in the Rocky Mountains is one on the Gunnison National Forest, Colo., which is 34 inches in diameter and 100 feet tall. On the Deerlodge National Forest in Montana is a tree 26 inches in diameter and 115 feet tall, containing six 16-foot logs and scaling approximately 1,000 board feet. Individuals over 30 inches in diameter have been found at other places in the lodgepole region. In California there are individuals much larger in diameter than any mentioned, but these are usually short and limby.

Lodgepole pine seldom attains a very great age because of fire and insect damage. Stands over 250 years old are uncommon, and stands over 300 years very rare. The oldest stand on record is one on the Beaverhead National Forest, Mont., which has attained an age of about 450 years.

As a forest tree lodgepole characteristically forms a straight, slim, gradually tapering trunk with a compact, conical crown. In very dense stands trees which have been crowded throughout life may have extremely narrow crowns with a spread of only 3 or 4 feet and occupying only from 10 to 20 per cent of the stem length. In such cases the crown is usually irregular, and often appears as a mere bush at the top of the tree. In stands of moderate density the crown is still characteristically narrow, though more regular, and occupies from one-half to one-third of the stem length. Even in open-grown stands the crown seldom spreads more than from 16 to 20 feet, but the branches often come down nearly to the ground and the taper is usually rapid.

CLIMATIC, SOIL, AND MOISTURE REQUIREMENTS.

The climate of the lodgepole region is comparatively dry. Table 1 gives the essential climatological facts, so far as they are available from United States Weather Bureau reports. It indicates roughly the precipitation requirements of the various forest types of the region, data being given for stations in open country below timber line, where there is too little moisture to permit natural tree growth, up through the various timber types to the area above timber line.

Lodgepole will probably grow only where the average annual precipitation is 18 inches or more. As a rule the best-developed stands occur where the precipitation exceeds 21 inches. It is not total precipitation alone, but the amount of available moisture in the soil, which determines the possibility of tree growth. This latter

varies with the degree of slope, ground cover, and the permeability, kind, and depth of soil, and its degree of exposure to wind and sun. Air humidity also plays a part.

TABLE 1.—*Climate within the lodgepole region.*

[Compiled from United States Weather Bureau reports.]

Station.	Type of land or forest at station—timbered or open.	Approximate period on which averages are based.	Elevation.	Annual precipitation.			Annual temperature.		
				Mean.	Maximum.	Minimum.	Mean.	Maximum.	Minimum.
Colorado:		*Years.*	*Feet.*	*In.*	*In.*	*In.*	*Deg. F.*	*Deg. F.*	*Deg. F.*
Gunnison	Below timber line	21	7,670	9.48	13.45	6.86	37.0	96	−46
Moraine	Yellow pine	23	7,775	16.13	22.37	11.74	40.8	90	−32
Marble	Lodgepole	4	7,951	29.60	35.66	21.82	40.2	90	−29
Grand Lake	do	5	8,153	17.66	22.74	12.80			
Georgetown	Yellow pine (cut over)	11	8,550	12.82	19.05	11.72			
Longs Peak	Lodgepole	18	8,600	20.00	29.84	13.93	37.8	85	−31
Redcliffe	do	20	8,695	20.70	30.02	10.96			
Columbine	Engelmann spruce	3	8,766	25.00					
Frances	Lodgepole	8	9,300	25.89	33.72	21.65	40.6	86	−14
Breckinridge	do	24	9,536	23.90	46.41	14.22	33.7	90	−37
Spruce Lodge	Engelmann spruce	5	9,600	31.64	36.12	26.02			
Leadville	Open	15	10,248	14.98	23.76	11.75	35.0	83	−27
Carona	Above timber line	6	11,660	45.87	58.32	35.90	26.2	67	−30
Wyoming:									
Centennial	Below timber line	10	8,074	18.59	27.68	5.14	38.8	40.2	−37.9
Woodrock[1]	Lodgepole	1	8,500	44.39	44.39				
Dome Lake[2]	Alpine	2	8,821	34.78			30.7		
Yellowstone National Park:									
Fort Yellowstone.	Juniper	9	6,200	16.93	20.35	13.31	38.3	40.2	−36.3
Tower Falls[3]	Douglas fir	3	6,250	16.27	19.29	13.63	35.6	39.3	−33.6
Riverside[3]	Lodgepole	4	6,500	19.58	23.85	14.38	35.3	36.8	−33.9
Sylvan Pass[3]	do	4	7,000	25.48	27.72	24.03	34.2	34.7	−33.7
Snake River[3]	do	4	7,000	27.79	33.77	21.32	34.6	36.2	−33.2
Fairview[3]	Douglas fir	6	7,000	16.11	18.83	11.51	34.9	37.0	−32.9
Fountain[3]	Lodgepole	3	7,220	17.90	19.07	15.88	33.2	35.8	−31.5
Geyser Basin[3]	do	4	7,395	21.23	22.69	19.33	34.4	36.2	−31.6
Norris[3]	do	3	7,500	19.23	22.62	17.13	33.4	35.8	−30.4
Lake Yellowstone.[3]	do	5	7,733	25.04	42.15	17.39	31.2	33.7	−29.4
Grand Canyon[3]	do	2	7,900	25.72	27.81	23.62	31.9	33.1	−30.7
Montana:									
Helena	Below timber line	33	4,110	13.42	19.94	6.71	43.3	103	−42
Livingston	do	14	4,488	14.36	19.96	10.68	45.8	106	−34
Bozeman	do	33	4,700	18.72	32.63	14.18	43.2	112	−53
Anaconda	Juniper	11	5,300	14.99	18.89	9.03	42.1	96	−33
Butte	Below timber line	18	5,716	13.80	20.55	6.95	42.1	94	−29
Pipestone Pass	Douglas fir	3	5,800	18.87	19.66	17.61			
Bowen	Below timber line	6	6,060	13.75	18.56	10.10	32.7	90	−55
Fish Creek	Lodgepole	3	7,800	23.31	24.70	20.69	35.1	80	−22

[1] Probably reaches freezing every month; no temperature record.
[2] Likely to get freezing temperature any month.
[3] Freezing temperatures every month in year.

TABLE 1.—*Climate within the lodgepole region*—Continued.

Station.	Type of land or forest at station—timbered or open.	Approximate period on which averages are based.	Mean annual snowfall.	Killing frost.			
				Spring.		Fall.	
				Average latest.	Latest known.	Average earliest.	Earliest known.
Colorado:		*Years.*	*Inches.*				
Gunnison	Below timber line	21	46.5	July 10	(1)	Aug. 20	(1)
Moraine	Yellow pine	23	96.1	June 17	(1)	Aug. 18	(1)
Marble	Lodgepole	4	157.4	June 16	July 5	Aug. 26	Aug. 3
Grand Lake	do	5	173.2	(2)	(2)	(2)	(2)
Georgetown	Yellow pine (cut over)	11	94.0	(2)	(2)	(2)	(2)
Longs Peak	Lodgepole	18	119.5	July 10	(1)	Aug. 28	(1)
Redcliffe	do	20	205.4	(2)	(2)	(2)	(2)
Columbine	Engelmann spruce	3	211.5	(2)	(2)	(2)	(2)
Frances	Lodgepole	8	183.5	May 29	June 14	Sept. 10	Aug. 25
Breckinridge	do	24	193.9	July 21	(1)	Aug. 9	(1)
Spruce Lodge	Engelmann spruce	5	270.7	(2)	(2)	(2)	(2)
Leadville	Open	15	134.9	June 15	June 21	Aug. 31	Aug. 3
Carona	Above timber line	6	346.5	July 18	(1)	Aug. 19	(1)
Wyoming:							
Centennial	Below timber line	10	134.8	June 23	July 9	Sept. 8	Aug. 25
Woodrock[3]	Lodgepole	1	321.1	(3)	(3)	(3)	(3)
Dome Lake[4]	Alpine	2	223.2				
Yellowstone National Park:							
Fort Yellowstone.	Juniper	9	96.7	May 14	June 3	Sept. 19	Aug. 25
Tower Falls[5]	Douglas fir	3	86.9				
Riverside[5]	Lodgepole	4	102.0				
Sylvan Pass[5]	do	4	140.9				
Snake River[5]	do	4	218.8				
Fairview[5]	Douglas fir	6	73.0				
Fountain[5]	Lodgepole	3	126.0				
Geyser Basin[5]	do	4	156.8				
Norris[5]	do	3	153.2				
Lake Yellowstone.[5]	do	5	181.3				
Grand Canyon[5]	do	2	158.5				
Montana:							
Helena	Below timber line	33	54.7	May 7	June 9	Sept. 28	Sept. 5
Livingston	do	14	40.4	May 20	June 20	Sept. 17	Do.
Bozeman	do	33	71.1	May 28	do	Sept. 7	Aug. 9
Anaconda	Juniper	11	40.6	June 17	July 8	Sept. 6	Aug. 14
Butte	Below timber line	18	55.2	June 5	June 26	Sept. 15	Sept. 5
Pipestone Pass	Douglas fir	3	101.3				
Bowen	Below timber line	6	70.1				
Fish Creek	Lodgepole	3	182.5				

1 Midsummer.
2 No data.
3 Probably reaches freezing every month; no temperature record.
4 Likely to get freezing temperature any month.
5 Freezing temperatures every month in year.

In southwestern Montana lodgepole occurs at elevations as low as 4,500 feet on northern exposures, where there is the greatest atmospheric humidity and the least evaporation from the soil. South slopes at this elevation, if timbered at all, usually support only such species as juniper (*Juniperus scopulorum*) or Douglas fir (*Pseudotsuga taxifolia*), which require less soil moisture than lodgepole and are better constituted to resist transpiration. Lodgepole is found on southern exposures at about 6,000 feet, provided the gradient is less than 10 per cent. A steep south slope is generally too dry for the species.

At the upper limit of its range lodgepole gives way to other and more tolerant trees. Increase in soil and atmospheric moisture encourages such species as Engelmann spruce (*Picea engelmanni*) and

Alpine fir (*Abies lasicarpa*), while the relatively short growing season at high elevations does not furnish the total amount of heat which lodgepole needs for its growth. The range of the species is thus limited on one hand by lack of moisture and on the other by lack of heat.

Lodgepole occasionally endures for short periods extremes of temperature varying from approximately 100° F. to —55° F. The growing season of the region is short, since killing frosts are likely to occur until about the middle of June and the first autumn frost comes early in September. In the lodgepole zone frost and snow may occur at any time during the growing season.

May and June are the months of heaviest precipitation, but in the lodgepole zone much of this is in the form of snow, which usually covers the ground until late April or the middle of June, depending upon the elevation and aspect.

Too much soil moisture is unfavorable to lodgepole, and good drainage is essential. The tree will not stand a water content of more than 35 per cent in a loam soil and only about half as much in gravel or sand. The best water content is between 12 and 15 per cent, though in gravel it may even fall below 5 per cent without effect upon the tree beyond a decrease in its rate of growth.[1] In respect to their moisture requirements the different conifers of the region may be grouped as follows, those demanding the least moisture being placed first: Juniper, limber pine (*Pinus flexilis*), yellow pine (*Pinus ponderosa*), Douglas fir, lodgepole, white bark pine (*Pinus albicaulis*), Alpine fir, and Engelmann spruce.

Lodgepole is not exacting in its soil requirements, though it does best on deep, fresh, well-drained agricultural land. It is able to make good growth, however, on shallower, poorer soils, provided a reasonable amount of moisture is available. The typical soil of the lodgepole region is gravelly, with a considerable admixture of loam in valley bottoms and open benches, but with little or none on ridges and steep slopes. Unless lightened by a mixture of sand, gravel, or loam, clays are usually not well enough drained, while limestone soils are apt to be too dry to enable the tree to make a normal growth. In the Big Horn Mountains in Wyoming, for example, lodgepole is rarely found on the limestone soils, though granitic soils immediately adjoining show extensive areas of the lodgepole type.

LIGHT REQUIREMENTS.

In relation to light, lodgepole pine exhibits three striking characteristics—intolerance of any considerable degree of overhead shade; ability to survive for long periods in a badly crowded or suppressed condition in pure, even-aged stands; and ability to recover and make

[1] Forest Service Bulletin 79, The Life History of Lodgepole Burn Forests.

increased growth after being released from suppression. For its best development lodgepole requires considerable light from above. With full sunlight as standard, no vigorous seedlings were found in Colorado in light values of from 0.08 to 0.05. Since the light values in mature forests range from 0.12 to 0.05, with an average of 0.08 or 0.07, it is obvious that satisfactory reproduction can not be expected in such stands.[1] Seedlings often start under the partial shade of moderately open stands, particularly in restricted groups in small openings, but their growth and development is slower than in the open. Full sunlight will result in the best development at all ages, provided sufficient soil moisture is available. In the order of their tolerance the species of the lodgepole region may be grouped as follows: Alpine fir, Englemann spruce, Douglas fir, white bark pine, lodgepole pine, yellow pine, limber pine, juniper.

Although not as tolerant as most of its associates, lodgepole is truly remarkable for its ability to live for long periods in a badly-suppressed condition in the shade of larger trees of the same species. It is this characteristic which makes dense reproduction undesirable. The extremely dense stands which follow fire will remain dense indefinitely to the practically complete stagnation of growth. Some stands over 50 years old have more than 50,000 live trees per acre from 8 to 10 feet high. On Buffalo Creek on the Deerlodge National Forest, Mont., in a 70-year-old stand on a north slope, a count on 1 square rod in a fairly typical situation showed a density at a rate of 101,000 live trees per acre, together with 79,000 dead ones. (Pl. I, fig. 2.) The "trees," which could be pulled up like so many weeds, had an average diameter of about three-tenths inch at 1 inch above ground and a height of about 4 feet. The largest tree was 8 feet high and 1.5 inches in diameter. The wonderful persistence of the individual is shown by the loss of only 45 per cent in numbers after 70 years of crowding. This behavior of lodgepole, which is evident in Colorado and Wyoming, as well as in Montana, contrasts strongly with that of yellow pine, an area of which near Missoula, Mont., showed only 1,300 live trees per acre after 30 years in a stand which had originally numbered 3,500 trees per acre. Of the surviving trees, moreover, 310 completely dominated the rest.

In overdense stands of lodgepole the side branches are killed by shading for the better part of the distance up the bole. In moderately dense stands, however, natural pruning of the side branches is not extensive enough to result in the production of clean stems. It has been estimated that reproduction at the rate of about 8,000 seedlings per acre is necessary to secure a high degree of natural pruning. In a stand of 1,500 to 2,000 seedlings per acre, well distributed, the lower side branches will remain small and die at an early age. Many

[1] Forest Service Bulletin 79, History of Lodgepole Burn Forests, and Forest Service Bulletin 92, Light in Relation to Tree Growth.

of these dead branches will, of course, persist for years, but they will not be large enough to detract from the value of the timber for the purposes to which it is best suited. Even this moderate density would be undesirable, however, if the stand could not be thinned fairly early in its life—when from 40 to 60 years old. Trees which have come up in openings in stands grow more slowly than trees which start in full sunlight, but, on the other hand, develop small side branches on the lower stem and in the end produce better timber.

In a typical dense stand of merchantable lodgepoles there is usually a large number of suppressed trees from 2 to 6 inches in diameter. These are not younger than the larger trees in the stand, as might be supposed, but are generally of about the same age.

There is a general belief that lodgepole will not recover from suppression when openings are made in the stand. Recent investigations, however, prove that recovery does take place and often to a remarkable degree. The photograph of the cross section of lodgepole pine (Pl. II) shows the effect of a very heavy thinning in which the stand was well opened. This particular cross section was selected for photographing because the rings formed previous to the release are large enough to show, which is not the case in many badly suppressed trees.

Another tree studied was released from suppression 16 years ago, when 94 years old. Since then its diameter has increased from 1.44 inches to 5.06 inches and its height from 15 feet to 25 feet. The rate of growth has increased from 1 inch in diameter in 67 years to an inch in 4 years and from 1 foot in height in 7 years to 1 foot in 1.6 years. After its neighbors were removed the rate of diameter growth increased immediately, but for the first 8 years it grew in height only at the rate of 1 foot in 4 years. During the last 8 years, however, it has been growing in height uniformly at the rate of a foot a year. The rate of volume growth has increased 4,680 per cent.

Another tree which, at the age of 50 years, had a stump diameter of nine-tenths of an inch and a height of 5 feet, was opened to the light by a cutting made 43 years ago. After 43 years of sunlight the tree had grown to a diameter of 6.6 inches and a height of 27 feet. The volume of wood produced in the period of accelerated growth was about 25,600 per cent more than that produced during the period of suppression.

Even small seedlings which have been badly suppressed will respond vigorously when the stand is well opened. A seedling about 30 years old, three-tenths of an inch in diameter at the ground, and $2\frac{1}{2}$ feet high, grew to a diameter of seven-tenths of an inch and a height of 6 feet in 5 years after its release.

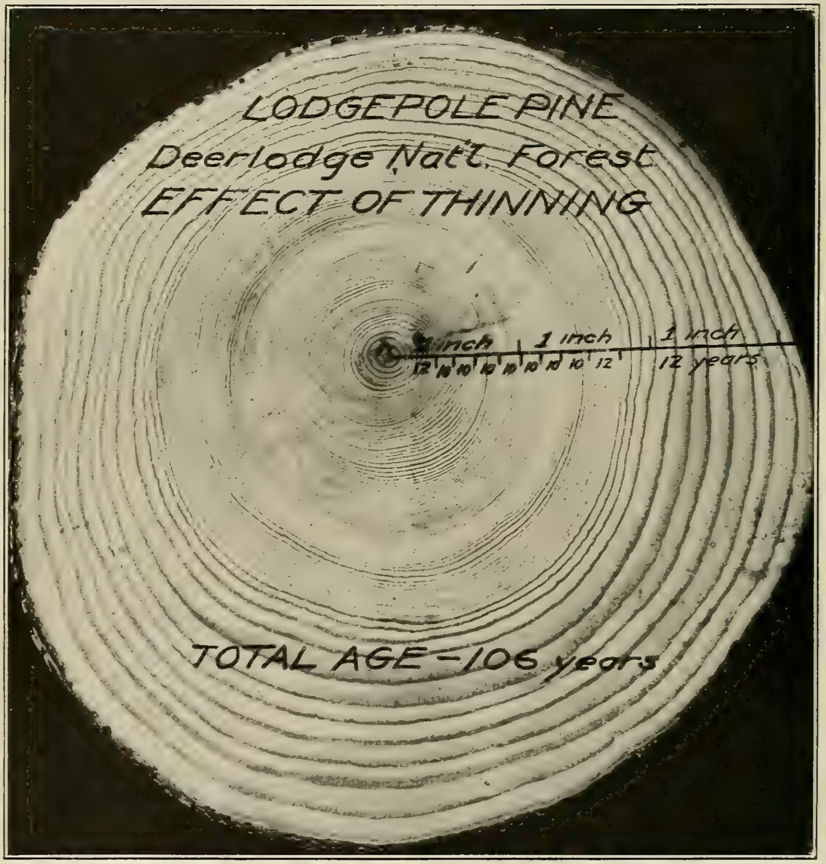
Whether or not a tree will recover from suppression depends upon the condition of its crown at the time of release, the amount of light

FIG. 1.—DENSE LODGEPOLE REPRODUCTION.

This stand is the result of fire. It runs about 3,500 green trees per acre and is about 50 years old. Many of the larger trees are suitable for lagging. The stand should be thinned as soon as possible so that the better trees left may grow rapidly to stull size.

FIG. 2.—DENSE LODGEPOLE REPRODUCTION.

This 70-year-old stand, situated on a north slope, has approximately 101,000 green "trees" per acre, with resulting stagnation in the growth. The better trees bear cones. Note the débris from the previous stand only partially decayed after being dead 70 years.



EFFECT OF THINNING LODGEPOLE.

After its release this tree increased in diameter from 3.5 to 6.3 inches in 12 years. In the last 12 years the tree has been growing at the rate of an inch in diameter in 4 years, while in the previous 12 years it had been growing at the rate of an inch in 25 years. The tree has been growing 772 per cent faster in volume in the last 12 years than in the preceding 12 years. Note the thin bark.

admitted to the stand, and probably to some degree upon the tree's height. Tall trees with very poor crowns are often killed outright when exposed to full sunlight. The more thrifty and vigorous the crown and the shorter the tree, the surer the recovery. Trees which stand full light immediately show the greatest increase in growth. Observations made so far do not tend to show that the quality of the site has any effect upon recovery from suppression.

REPRODUCTION.

CONE AND SEED PRODUCTION.[1]

Lodgepole pine usually produces a fair crop of seed each year. Particularly abundant seed production may occur at two or three year intervals, but it is not yet possible to say whether there is any uniform periodicity in such years, as is often the case with yellow pine and Engelmann spruce. Open-grown trees produce seed at an earlier age and in larger quantities throughout life than do trees in dense stands. Seedlings in the open have been known to mature cones at the very early age of 5 years, while crowded trees in the forest may reach an age of 50 years without doing so. In somewhat open stands moderate seed production usually begins when the trees are from 15 to 20 years old. Careful tests show that seed from trees less than 10 years old have as high a germination per cent as seed from mature trees.

Typical lodgepole cones vary in diameter from 1 to 2.5 inches. The cones are generally larger on open-grown than on close-grown trees, and tend to increase in size with the age of the tree up to its maturity. They are nearly always flattened on the side oppressed to the parent branch. The extreme basal scales of the cone and from 3 to 6 scales at the tip do not bear any seeds, but the remainder of the scales, between base and tip, nearly always do. Seed-collecting operations on nine National Forests in Colorado and Wyoming show an average of about 26 seeds per cone. The number of cones per tree, and consequently the total seed production, varies greatly. Clements has estimated the average annual production of seed per tree in certain cases at from 21,000 to 50,000. Hence the total seed production of a stand may be enormous. Lodgepole is unquestionably a more prolific and regular seed producer than any of the species commonly associated with it.

SEED DISSEMINATION.

Lodgepole cones ripen in late August or September of their second year. It is a notable characteristic of the species, however, that the cones often fail to open and discharge the seed as soon as mature.

[1] Detailed results of an investigation on this subject made by F. E. Clements in Colorado are given in Forest Service Bulletin 79.

Sealed cones as old as 75 and 80 years have been found attached to the parent tree. Sometimes the lower part, or even the entire cone, is embedded in the wood. Closed cones are more common on old than on young trees, and on trees growing in dense stands than on those in the open. MacDonald found on the Targhee Forest that on trees less than 55 years old five-sixths of the cones opened at maturity, while on trees over 55 years old only one-fourth of the cones opened. Seeds retain their vitality for many years in sealed cones, and in one case had a germination per cent as high as 8 after being locked up for about 75 years.

Clements states that cones open normally as a result of the drying out of the cone scales rather than from the action of heat alone. The majority of cones capable of opening normally probably do so within a short time after maturity, and scatter their seeds while still attached to the tree. Some cones, however, after remaining upon the tree closed or only partly open for a number of years finally fall to the ground with more or less seed still in them.

There appear to be two distinct periods of general opening, the first in the years immediately following maturity and the second from 10 to 13 years later. The opening during the second period is probably due to the fact that the pedicel of the cone breaks about this time and the cone no longer receives moisture from the tree. The size of the cone appears to have no effect upon the time when it opens.

Tower[1] states that the amount of lime in the soil has a strong influence upon the time when the cones open; that on soils rich in silica and deficient in lime the majority of cones open at maturity, while on soils rich in lime they remain closed and persist on the trees for many years. Observations by other investigators in Colorado and Montana, however, indicate that this tendency is not sufficiently marked to constitute a rule. Individual trees in the same stand show the most extreme differences in cone opening; one tree may have all of its cones open, while beside it another tree of the same age may have all of its cones closed; and in most cases both open and closed cones are found on the same tree. Probably the differences in behavior in this respect observed by Tower indicate merely the general tendency of cones to open less promptly on dry soils. This tendency is also indicated by the fact that fewer cones remain closed on the moister soils and in the moister climates of northwestern Montana, northern Idaho, and the Sierras in California.

The opening of the cone frees the small, winged seeds, which are distributed mainly by the wind. Other agents of seed distribution are gravity, surface drainage and streams, and such animals as squirrels and mice. The distance to which wind distribution is effec-

[1] A Study of the Reproductive Characteristics of Lodgepole Pine, by G. E. Tower, in Vol. IV, No. 1, of the Proceedings of the Society of American Foresters.

tive is very apt to be overestimated. One reason for this is that natural reproduction has often been credited to wind-sown seed, when in reality the seed was already present on the area in sealed cones. Hodson,[1] as the result of a study on a large number of cut-over areas in Montana and Wyoming, concludes that "the largest amount of seed falls within a hundred feet of the seed tree, and the radius of effective reproduction is much less than is commonly supposed." Clements states that the distance to which seed is carried by the wind "was never found to exceed 164 feet." Undoubtedly the distances seeds are carried varies considerably with the topography and the situation of the seed trees. Trees on a ridge exposed to high winds will distribute seed the maximum distance. Until more definite information is available, it is safe to assume that wind distribution should not be relied upon for distances of more than 150 to 250 feet, according to the character of the situation.

REQUIREMENTS FOR NATURAL REPRODUCTION.

Owing to its intolerance of overhead shade, lodgepole pine will not reproduce satisfactorily without considerable direct light. Although the seed will germinate with a vary small amount of light, the young seedling soon dies without it. In mature stands a heavy thinning which reduces the crown density to about one-half is usually necessary to permit a fair amount of reproduction to start and thrive. Where the stand is opened by the removal of groups of trees on areas of 3 or 4 square rods or more, reproduction will usually start and grow well in the openings. Reproduction starting in this manner is more apt to be uneven aged and better divided into height classes, and consequently in less danger of stagnation, than in the dense, even aged stands of uniform height which so often follow fire. Vigorous young growth has been observed under stands in which a heavy and uniform thinning had been made, causing the forest to resemble one undergoing regeneration by the shelterwood method. In stands of only moderate density, however, seedlings are apt to be spindling and slow of growth.

The most favorable seed bed for germination of lodgepole pine seed is a mineral soil with plenty of available heat and moisture. Needles and undecayed humus are apt to dry out rapidly in the spring, before the rootlets of most of the seedlings can reach the mineral soil. That mineral soil is not always necessary for germination, however, is shown by the fact that on old cuttings in Montana where there has been no fire, seedlings apparently start indiscriminately on patches of mineral soil and in small clumps of pine grass

[1] Silvical Notes on Lodgepole Pine, by E. R. Hodson, in Vol. III, No. 1, of the Proceedings of the Society of American Foresters.

(*Calemagrostis rubescens*), the latter usually not more than 8 or 10 inches high. Furthermore, in full sunlight even mineral soil may dry out so rapidly that many of the seedlings will be killed by drought. For this reason young stands are usually more dense on mineral soil lightly shaded by recently fire-killed trees than in the open. On the other hand, they are likely to be more open on sandy soil than on soils better able to retain moisture. The densest seedling stands are apt to occur on north slopes where there is a relatively small amount of direct sunlight and a large amount of moisture.

Competition with other native vegetation, such as blueberry (*Vaccinium*) and kinnikinnic (*Arctostaphylos*), for light and soil moisture often greatly reduces the amount of lodgepole reproduction; and the seedlings which do start have a much slower growth than where there is no competition. Aspen also is a hindrance to lodgepole, through its more rapid growth when young, wherever the two start on the same area. A light, overhead aspen cover, on the other hand, may be beneficial by protecting the soil.

Rodents reduce the seed supply to a certain extent, but there is probably always enough seed left for satisfactory reproduction if other conditions are favorable.

OPTIMUM DENSITY.

The right density for a stand of lodgepole is that at which the lower branches become suppressed and die while still small, but without overcrowding of the trees and consequent decrease in rate of growth. Hodson concluded that an original density of 8,000 seedlings per acre is required to produce clean stems at maturity. Later investigations show, however, that while this number of seedlings would secure good natural pruning, it would be at a great sacrifice in diameter growth. In the reconnaissance work on the Deerlodge Forest a "normal" seedling stand is considered one of about 1,000 trees per acre, fairly well spaced and of fairly even height growth. By "normal" is meant that degree and character of stocking which will produce the maximum yield of merchantable timber of the desired sizes at the end of the rotation. Stands containing too few, or too many, unevenly distributed trees, are abnormal to the extent to which they will fail to produce this maximum yield. Normality is thus seen to differ materially from "density," which refers to the extent to which the crown space is fully utilized. Stands with a density of 1.0 are nearly always too crowded for the most satisfactory development.

The number of trees constituting a normal stand naturally decreases with the age of the stand. While 1,000 trees per acre, evenly spaced, is a satisfactory stocking when reproduction first starts, this

FIG. 1.—LODGEPOLE TIMBER.

Heavy stand of overmature stull timber about 200 years old, Deerlodge National Forest.

FIG. 2.—WELL-DEVELOPED YOUNG LODGEPOLE.

This stand is 60 years of age and now has about 250 trees per acre. The thinning was made 18 years ago, which removed about 250 trees per acre, although at that time the density was about normal. The stand now has 3,200 board feet per acre.

FIG. 1.—LODGEPOLE REPRODUCTION.

In the center of the picture is a 20-year-old stand of lodgepole on an old cutting. No fire has been over the area. The white streaks mark the location of the original windrows of brush only partly decayed.

FIG. 2.—LODGEPOLE REPRODUCTION.

Well-distributed seedlings coming up without fire on a cutting made 10 years ago. The stand is about 500 per acre, a density nearly ideal.

should be reduced to about 500 at the end of 30 years, to about 300 at the end of 90 years, and to about 250 by the one hundred and fortieth year, when the stand may be considered mature. Unfortunately, owing to the low mortality rate of lodgepole pine, a stand of 1,000 evenly distributed seedlings 10 years old will not, by natural means, be reduced to 500 at 30 years, 300 at 90 years, and 250 at 140 years. Ordinarily this could be brought about only by thinning. If, however, the stand is sufficiently open to arrive at maturity with 250 stems per acre without thinning, decidedly limby trees will be the result. On the other hand, a stand of 1,000 well-spaced seedlings 10 years old, at which age a stand may be considered as established, probably will have about half that number of trees at maturity. In such a case those of fairly good form and diameter may be cut and the others left to grow for an additional period. Seedling stands of from 300 to 500 plants per acre are preferable to those of 8,000 or more, even when thinning is possible, since for many years the latter will not produce material which can be taken out with profit in the course of thinning. Thinnings, moreover, will probably be impracticable, except in a few localities, and for this reason from 300 to 500 seedlings may generally be considered preferable to 2,000 or more. A good volume of limby timber is better than a large number of poles; besides, the spaces in an open stand will gradually fill in with individuals of a more satisfactory form. Where thinnings are practicable a density of about 2,000 plants at the start is best. Plate III, figure 2, shows a well-developed 60-year-old stand of lodgepole of something less than normal density.

It should be borne in mind that the figures for density given in the preceding paragraph are more or less arbitrary, and in determining the normality of a stand as much attention should be given to the spacing and height growth as to the number of stems. A relatively large number of trees per acre is not undesirable, provided there is enough variation in the height of individual trees to prevent stagnation of growth.

The production of clean stems is of comparatively little importance, since lodgepole is used mainly for mine timbers and railway ties, and in the future is not likely to have additional uses other than for telephone poles, pulp, and common lumber. Of far greater importance than clean stems are rapid growth and the production of large-sized timber. Lodgepole is slow-growing, and there is always an abundance of trees of small size. Ordinarily there is far greater danger of overstocking than of understocking. Observations on 40,585 acres of young growth on the Deerlodge National Forest show 78.7 per cent of the entire area to be overstocked, 20.5 per cent understocked, and only 0.8 per cent normally stocked.

EFFECT OF FIRE.

Fire has been one of the most important agencies in the reproduction of lodgepole pine. Its effect is fourfold: (1) By softening the resin and drying out the cone scales it opens the sealed cones and makes available the accumulated seed production of many years; (2) by reducing the density of the ground cover it admits plenty of light; (3) by exposing the mineral soil and removing the ground cover it prepares a favorable seedbed; (4) by killing and driving away for a time the rodents and birds it saves the seed from being eaten. Thus aided by fire, lodgepole has been able to replace to a considerable extent all the species within its range, since these usually produce seed in abundance only once in several years and discharge it immediately. Most of the extensive lodgepole stands now in existence have come in as a result of fire. On the other hand, areas formerly covered with lodgepole have been made barren by "double burns," where stands of young growth which followed the first fire have been destroyed by a second one before they were old enough to produce seed. Areas of this kind on which all of the trees have been killed will not reforest naturally for many years, since the only way reproduction can take place is by seeding from the sides.

Fire in a mature stand is usually followed by too dense a reproduction to permit the most satisfactory development of the young trees. Sample plots on the Gallatin National Forest, Mont., show reproduction after the fires of 1910 with a maximum density of about 300,000 one-year-old sedlings per acre. On the Deerlodge National Forest stands following fire have been found which, at the age of 8 years, had a maximum density of about 175,000 live seedlings per acre, averaging about 2 feet high. Ten small sample plots on the Arapaho National Forest, Colo., in a 22-year-old stand, showed an average of nearly 44,000 trees per acre. These figures, of course, represent maximum densities on small areas, but as extreme illustrations they show that severe overstocking is more than likely to follow fire.

The effect of fire on cut-over areas may be very different. Where all the trees have been felled and the brush piled in windrows—a practice in many private operations—a fire in the slash may be followed by reproduction of moderate density. Such a fire usually destroys all the seeds in the windrows, the locations of which are marked by the absence of reproduction, while a moderately dense stand starts in the intervening spaces from cones which did not get into the windrows and thus escaped destruction.

On unburned, cut-over areas reproduction is apt to be much less dense, and therefore more satisfactory than in the case of burned-over uncut stands. Throughout the Rocky Mountains are thousands of acres of old cuttings, untouched by fire, upon which the reproduction is decidedly satisfactory. This is especially true of the Deerlodge Forest, near Butte, Mont., where it is unusual to find an old

cutting on which reproduction is not taking place. Observations on 32 separate tracts in the 20 and 30 year age classes on this Forest show a far more satisfactory reproduction on unburned cut-over areas than where stands have been killed by fire. On many clean-cut areas which have been left practically without seed trees reproduction has taken place solely from cones which remained on the ground after logging. Nearly all mature trees bear a considerable number of persistent, closed cones, some of which fall on the ground when the tree is cut, while others remain attached to the branches. These gradually open and drop their seed, resulting in fairly uniform reproduction if the brush is scattered. If it is piled in windrows, which decay very slowly, the spaces so occupied will not reproduce. (Plate IV, fig. 1.) Where the stand is not cut clean, or where clean-cut only over small areas, seed comes from above or from the side, as well as from the cones left on the ground and in the tops of felled trees. Sample plots in an unburned stand on the Arapaho National Forest, measured six years after the removal of about one-half of the original trees for ties, showed an average of 6,000 seedlings per acre, of which 3,500 had started since the cutting. Even with the same number of seedlings per acre reproduction is apt to be more satisfactory on an unburned than on a burned area, since the young growth comes in more gradually, giving trees of different heights and so materially lessening the danger of stagnation.

The greater part of the reproduction which comes in after either fire or cutting usually starts within a comparatively short time. The following figures, which represent averages obtained from 181 small sample plots, both burned and unburned, in Montana and Wyoming, show the proportion of reproduction which came in during each 5-year period for the first 30 years after the stand was opened up:

	Per cent.
First five years	69.5
Second five years	21.0
Third five years	5.4
Fourth five years	.9
Fifth five years	2.5
Sixth five years	.7
	100.0

It will be seen that nearly 70 per cent of the reproduction started in the first 5 years and over 90 per cent in the first 10 years. Unfortunately, it is not possible to separate the figures for burned and unburned plots. Similar observations on a 9-year-old burn on the Arapaho National Forest showed over 49 per cent of the reproduction to have started in the first four years and nearly 75 per cent in the first six years after the fire. In most places the character of the seedbed is so changed in the 10 years following a cutting or fire by

the formation of a thick sod of grass that comparatively few seedlings are able to gain a foothold after that time.

GROWTH.

The rate of growth of lodgepole varies greatly with the quality of the site and the density of the stand. Other conditions being the same, the most rapid growth takes place on the best sites, but overstocking often reduces the rate of growth in such situations to a point at which it is considerably less than in more normally stocked stands on poorer sites. The effect upon growth of the density of the stand is discussed under "Factors influencing yield."

On account of the wide variation in lodgepole's rate of growth, it is impossible to give figures which will be universally applicable. Table 2 shows what may be expected under certain conditions. The data were obtained from 468 average trees cut by the arbitrary group method in the course of a yield study on the Deerlodge Forest, conducted in fully stocked stands on sites better than the average for that Forest. Since the stands were approximately fully stocked, and in some cases overstocked, the diameter growth shown is somewhat less than that which may be expected in the case of trees growing in stands of moderate density. On the other hand, since the sites were better than the average, the height growth shown is somewhat above the average.

TABLE 2.—*Average growth of lodgepole pine in fully stocked stands on the Deerlodge National Forest, Montana, on slightly better than average sites, based on 468 average trees, of which 158 were dominant.*

Age in years.	Diameter breast high.		Height.		Volume.			
	Average trees.	Dominant trees.	Average trees.	Dominant trees.	Average trees.	Dominant trees.	Average trees.	Dominant trees.
	Inches.	*Inches.*	*Feet.*	*Feet.*	*Board feet.*[1]	*Board feet.*[1]	*Cubic feet.*[2]	*Cubic feet.*[2]
10	0.4	0.5	3	4				
20	1.2	1.9	10	12				
30	2.1	3.2	19	20			0.5	1.0
40	3.0	4.4	27	32			.9	2.5
50	3.8	5.6	33	38			1.5	3.9
60	4.5	6.6	38	44		5	2.1	5.5
70	5.2	7.4	42	49		20	3.0	7.4
80	5.8	8.2	47	54		35	4.1	9.5
90	6.4	8.9	51	58	5	45	6.2	12.2
100	6.9	9.5	54	62	20	60	8.6	15.3
110	7.4	10.1	58	66	30	75	10.0	18.5
120	7.9	10.7	61	70	40	90	11.4	23.0
130	8.3	11.2	65	73	50	105	13.5	26.0
140	8.7	11.8	68	76	60	120	15.5	30.0
150	9.2	12.3	71	79	70	135	18.0	34.5
160	9.6	12.8	74	81.5	80	150	20.0	39.0
170	10.0	13.3	77	84	90	170	22.0	44.0
180	10.4	13.8	80	86.5	100	190	24.2	49.0
190	10.8	14.3	83	89	110	215	26.5	54.0
200	11.2	14.7	85	91.5	125	240	30.0	60.0

[1] The board foot volume is based on a minimum log of 6-inch top diameter and 16-foot length, scaled by the Scribner Decimal C rule.
[2] The cubic foot volume includes only the usable portion of the trunk from above the stump, usually from 6 to 10 inches high, to a diameter of 3 inches in the top.

This table shows how comparatively slow is the growth of lodgepole pine. One of the most striking points brought out, however, is the relatively rapid growth of the dominant trees, particularly in volume, amounting to approximately twice that of the average tree. This indicates clearly the need for sufficient growing space if the maximum development of individual trees is to be secured.

Measurements which would permit of comparison between the rate of growth in Wyoming and Colorado with that in Montana are not available. Table 3, however, shows the diameter growth by decades on two widely separated Forests in Wyoming, the Medicine Bow and the Bighorn. In both cases the growth is typical of the average sites on which the bulk of the lodgepole forests of the region are found. Since in this case the measurements were collected by following the sawyers through the woods, the data secured represent the growth of trees of more than the average diameter, since only the larger timber was cut. Also, the stand on the Medicine Bow was probably denser than on the Bighorn, which accounts for the slower rate of growth upon the former. On similar sites, and with the same stand density, the rate of growth for the two Forests would probably be about the same.

TABLE 3.—*Average diameter growth of lodgepole pine on average sites on the Bighorn and Medicine Bow National Forests, Wyo.*[1]

Age in years.	Bighorn National Forest.[2] Diameter breast high.	Medicine Bow Forest.[3] Diameter breast high.	Age in years.	Bighorn National Forest.[2] Diameter breast high.	Medicine Bow Forest.[3] Diameter breast high.
	Inches.	*Inches.*		*Inches.*	*Inches.*
20	1.5	0.3	120	10.7	7.7
30	3.0	1.6	130	11.1	8.2
40	4.4	2.8	140	11.6	8.6
50	5.7	3.7	150	12.1	9.1
60	6.7	4.4	160	12.5	9.6
70	7.6	5.0	170	12.8	10.0
80	8.4	5.6	180	13.2	10.4
90	9.1	6.2	190	13.5	10.8
100	9.7	6.7	200	13.8	11.1
110	10.3	7.2			

[1] From Forest Service Circular 126, "Forest Tables: Lodgepole Pine."
[2] Based on decade measurements on 49 stumps of various heights, 72 to 340 years old.
[3] Based on decade measurements on 430 1-foot stumps, 159 to 300 years old.

The growth in height of young seedlings in Montana and Colorado is shown in Table 4. Figures for Montana are based on measurements of 86 trees on the Deerlodge National Forest made to determine the average age required to reach various stump heights; figures for Colorado are the results of measurements of reproduction on a burned area on the Arapaho National Forest. In the white-pine region of Northern Idaho lodgepole makes a more rapid height growth in the seedling stage than does any other species, with the

possible exception of larch. Lodgepole seedlings from 5 to 7 years old with leaders 36 inches long have been noted. In one case a young tree, about 8 years old, had made a height growth of 7½ feet in the last 3 years. Another young tree of about the same age had a 45-inch leader.

TABLE 4.—*Average height growth of lodgepole pine seedlings on the Deerlodge National Forest, Mont., and the Arapaho National Forest, Colo.*

Age in years.	Height.		Age in years.	Height.	
	Deerlodge National Forest.	Arapaho National Forest.		Deerlodge National Forest.	Arapaho National Forest.
	Feet.	*Feet.*		*Feet.*	*Feet.*
1		0.1	5	0.8	1.4
2		.2	6	1.0	1.9
3	0.4	.4	10		4.5
4	.6	.9	15		7.9

The growth figures so far given all apply to unthinned stands. If it were possible to make thinnings when needed that would favor the best trees, the growth of the latter would undoubtedly equal, or even considerably exceed, that shown for the dominant trees shown in Table 2. Such intensive management, however, could be undertaken only in a few favored localities where the market is unusually good. Lodgepole pine stands have been thinned in the past only in the course of ordinary lumbering, which has usually left the smaller, poorly developed trees, many of which could take no advantage of the operation. That even trees of this character often respond to such haphazard thinning with a remarkable increase in rate of growth has already been stated. Out of 91 average trees measured on the Deerlodge Forest, representing those which remained when the surrounding stand was cut, 54 trees, or 59 per cent of the total number, showed a marked increase in growth, while the remainder, or 41 per cent, showed no increase. Differences in rate of growth before and after cutting are shown in Table 5.

TABLE 5.—*Effect of thinning; average diameter growth of lodgepole pine trees left after cutting, Deerlodge National Forest, Mont.*

PART I. [Based on 91 trees, irrespective of whether they showed increased growth or not.]

Diameter breast high.	Trees.	Periodic annual diameter growth for 20 years.		Time required to grow 1 inch in diameter.	
		Before thinning.	After thinning.	Before thinning.	After thinning.
Inches.	*Number.*	*Inch.*	*Inch.*	*Years.*	*Years.*
3	8	0.028	0.034	36	29
4	10	.031	.042	32	24
5	15	.037	.039	27	25
6	17	.051	.041	20	24
7	17	.047	.057	21	18
8	15	.059	.064	17	15
9	6	.050	.046	20	21
10	3	.058	.054	17	18

TABLE 5.—*Effect of thinning; average diameter growth of lodgepole pine trees left after cutting, etc.*—Continued.

PART II. [Based on the 54 trees which showed an increased growth.]

Diameter breast high.	Trees.	Periodic annual diameter growth for 20 years.		Time required to grow 1 inch in diameter.		Rate of increase in volume growth after thinning.
		Before thinning.	After thinning.	Before thinning.	After thinning.	
Inches.	*Number.*	*Inch.*	*Inch.*	*Years.*	*Years.*	*Per cent.*
3	5	0.029	0.045	34	22	140
4	6	.030	.050	33	20	169
5	7	.023	.049	43	20	127
6	8	.029	.039	34	25	59
7	13	.038	.061	26	16	112
8	9	.047	.072	21	14	98
9	4	.027	.042	37	24	70
10	2	.022	.047	45	21	125

CAUSES OF INJURY.

FIRE.

Fire has been the most important agent in the destruction of lodgepole pine forests, as well as in their establishment. Though in some places it has enabled lodgepole to take possession of the ground, in others repeated fires have practically eliminated forest growth. Lodgepole pine is less susceptible to fire than Engelmann spruce and Alpine fir, but more susceptible than the other pines with which it grows or Douglas fir. Its susceptibility is due chiefly to its thin bark, which at stump height is only from two-tenths to four-tenths of an inch thick. Fire is most destructive in dense young stands of "jack pine," as the young trees are often called. Crown fires are infrequent, but may occur with high winds or when a large amount of débris litters the ground. When a lodgepole stand is killed by fire a period of from 15 to 30 years elapses before the dead trees fall to the ground. Fire-killed timber does not completely decay until from 60 to 120 years after the fire. Such débris, of course, greatly increases the fire danger in a new stand.

In comparatively open stands which have reached maturity without being burned over there is usually not much débris on the ground and consequently less danger of crown fires. Even here, however, there is in most cases a ground cover of grasses, weeds, needles, and similar litter to invite surface fires, which destroy reproduction, occasionally kill mature trees, and seriously injure the butts and lessen the vitality of many others. These ground fires, too, by destroying the organic content of the soil, reduce both its water-holding power and its productive capacity, which necessarily results in decreased growth of the surviving trees.

INSECTS.

Although lodgepole pine in the Rocky Mountains has not suffered severely from insect attack in recent years, bark beetles have undoubtedly killed more mature timber than has any other agency except fire. In Montana the mountain pine beetle (*Dendroctonus monticolae* Hopk.) has done some damage in the vicinity of Swan Lake on the Flathead National Forest, and in 1911 an aggressive attack by this beetle in the Big Hole Basin on the Deerlodge and Beaver Head Forests developed serious proportions.[1] In that year approximately 15,000 trees were killed on an area of about 1,500 acres. On some portions of the area practically all the trees over 5 inches in diameter were either killed or badly infested, while on the remainder of the area the attack was confined to the larger and less vigorous trees. The attack appeared to radiate from several centers where the damage was particularly severe. It appears likely that this infestation resulted largely from injury to the trees by adverse weather conditions during the winter of 1908–9, the insects taking advantage of the trees' weakened condition. The unusually dry summer of 1910 was also thought to have favored the attack. Fortunately many of the insects were destroyed during the winter of 1911–12, apparently by winter killing, to which the thin bark of lodgepole renders them liable.

In regions other than the one considered in this bulletin, damage by the mountain pine beetle has been very severe. On the Wallowa and Whitman National Forests in eastern Oregon it has recently killed 100,000,000 board feet of lodgepole. Here the infested area, which in 1906 covered only about a section, had by 1912 grown to approximately 320,000 acres, and the beetle was then extending its attack to yellow pine.

The presence of the mountain pine bark beetle is first made evident by pitch tubes, boring dust, and woodpecker work. Most of the adult beetles emerge during August, and by early fall are well established in their new hosts. The trees thus attacked usually remain green until the following spring, when their tops first turn a yellowish and then a reddish color. By the time the red-top condition is reached practically all the beetles have left the tree. The species apparently prefers to attack injured and felled trees; the more vigorous, and particularly the younger trees, are often able to drown the beetles in exudations of pitch. Thrifty trees, however, are sometimes killed.

In Wyoming and Colorado the most common insect enemy of lodgepole pine is the lodgepole pine beetle (*Dendroctonus murrayanae*

[1] For a complete description of this and other bark beetles of the genus Dendroctonus, together with methods of control, see Bureau of Entomology Bulletin 83, Part I, by Dr. A. D. Hopkins.

Hopk.). A few trees apparently killed by its attack have been found on the Medicine Bow and Bighorn National Forests in Wyoming, and on the Arapaho Forest in Colorado. The attack was confined mainly to the bases of the trees and to unhealthy individuals. The Oregon tomicus was also found, but it is probable that the dendroctonus made the first attack. A weevil similar to the eastern white pine weevil (*Pissodes strobi*) has also been found on the Arapaho National Forest. This insect destroys the terminal shoot, resulting in crooked and forked trees.

FUNGI AND MISTLETOE.

Lodgepole has, on the whole, suffered comparatively little damage from fungi. This is due chiefly to the dry climate of its range and to the fires which have renewed the stands from time to time, thus preventing any extensive development of the fungous diseases. Often badly fire-scarred trees may remain sound as long as 40 or 50 years, except for a small amount of blue stain along the edges of the scar. One of the two most common diseases of lodgepole is that caused by the ring scale fungus (*Trametes pini*), often called by woodsmen "white rot" or "red rot." Another common disease is caused by the fungus *Polyporus schweinitzii*. The ring scale fungus attacks chiefly the older trees, which it may enter at almost any point where a dead limb or wound affords an opening. From the point of infection it sometimes extends throughout the trunk. The wood at first turns a dark reddish brown, the trees at this stage being known to lumbermen as "red rot" or "red heart" timber. Later the color of the wood becomes lighter and small white spots and strands appear, increasing in size and number until the entire heartwood is filled with small holes lined with the thin, white cellulose of the wood which has not been used as food by the fungus. The wood never rots entirely away, but eventually becomes a mass of soft, spongy tissue.

The fungus *Polyporus schweinitzii* usually causes a heart rot at the butt. Since it is confined to the first or second logs it is less destructive than the ring scale fungus. When the roots are infected the tree may fall; in other cases it may break off close to the ground before the rot has had time to spread far into the trunk. The affected wood turns a light yellow and gradually dries out so that numerous fissures appear.

In overmature lodgepole stands from 7 to 10 per cent, or on limited areas even 15 to 20 per cent, of the timber may be affected by one or both of these fungi to an extent rendering it unmerchantable. It is seldom, however, that an entire tree is made worthless by rot, and one or more sound logs or ties can usually be obtained. The blue stain, which may appear almost immediately in the sapwood of fire-killed or insect-killed trees, does not render them unfit for use.

In some localities a rust (*Peridermium montanum*) attacks the leaves of lodgepole, causing them to fall prematurely. Another rust (*Peridermium harknessii*) attacks lodgepole in western Montana, causing galls to form on the trunk and branches, which stunts and sometimes kills the tree.

One of the false mistletoes (*Razoumfskya americana*) is often found on lodgepole, but does little serious damage except in certain localities, where it may greatly affect the growth of the tree. It usually attacks young stands, and in dense ones most of the trees may be infested. Mistletoe causes an abnormal growth at the point of attack, which on side branches forms a compact, bushy mass of twigs commonly called "witch's broom." In small trees infested stems or branches are sometimes swollen to twice their natural diameter.

SMELTER FUMES.

The Washoe smelter at Anaconda, just outside of the boundary of the Deerlodge National Forest, is the largest copper smelter in the world, handling approximately 10,000 tons of ore daily and producing 25 per cent of the copper output of the United States. Chemists have estimated that at least 2,500 tons of sulphur dioxide and at least 25 tons of arsenic trioxide are daily thrown into the atmosphere from the top of the stack. The arsenic does not damage the timber, but when deposited on the forage is injurious and sometimes fatal to grazing animals. Sulphur dioxide is injurious to vegetation in general. Experiments have shown that as little as one part of sulphur dioxide with a million parts of air will kill pine seedlings when the trees are exposed for any length of time. Even at a distance of many miles from Anaconda the air in the smoke stream may contain as many as 80 parts of sulphur dioxide to a million parts of air. At a distance of 10 miles from the smelter the sulphur is often so strong as to cause persons to cough.

Sulphur dioxide injures trees by destroying the chlorophyll in the leaves, which first turn yellow and later red-brown. The damage usually extends over several years, especially if the trees are at some distance from the smelter. At first only the weaker leaves are killed, but later the younger ones succumb to repeated baths in the smoke stream. Three stages in the defoliation of trees by smelter fumes have been recognized. The first is when the older leaves die and fall prematurely, the tree still retaining a considerable amount of foliage and the appearance of health. In the second stage the foliage becomes decidedly thin, and in the last or acute one only the needles of the current year are left green on the tree. (Plate V, fig. 1.) These latter are usually badly damaged or killed during the winter, and the tree may fail to put forth fresh leaves in the spring. In some cases, however, the acute stage lasts for several years. The an-

nual rings of trees injured or killed by smelter smoke usually show a graduated decrease in size for the last six or eight years.

With respect to their susceptibility to injury from smelter fumes, the species in the lodgepole region may be grouped as follows, the most easily killed coming first:

Alpine fir.
Douglas fir.
Lodgepole pine.
Engelmann spruce.
Juniper.
Limber pine.

As between Douglas fir and lodgepole pine, the two most important species in the smoke zone, the former is considerably more susceptible than the latter. Nearly all the lodgepole trees will remain green when practically all the Douglas firs in the same locality have been killed. Susceptibility varies among different individuals of the same species. A few green and flourishing Douglas fir trees will often be found after practically all the other firs in the vicinity have been killed.

The injury is not the same in amount at all places equally distant from the smelter, since the smoke is carried by the prevailing wind along channels formed by the topography. Damage decreases both with distance from the smelter and distance from the main channels. In places the smoke seems to eddy in a peculiar manner, killing trees in isolated groups. The greatest damage, of course, is close to the smelter, but at places 9 miles distant most of the lodgepole is now dead and the remainder seriously injured. Slight damage at a distance of 30 miles has been observed.

WINDFALL, SUN SCALD, ETC.

Lodgepole pine is generally regarded as being decidedly susceptible to windfall. While to a certain extent this is true, there is a tendency to exaggerate the danger. The extent of the development of the tree's root system, as in the case of any other species, varies with the soil conditions and the density of the stand. On deep, fresh soil trees in moderately open stands develop good root systems, while on very shallow or very moist soils the root system is correspndingly shallow and the tree less wind firm. With the same soil conditions, the development of the root system varies inversely with the density of the stand, so that the denser the stand the less windfirm are the individual trees. Experience shows that heavy thinnings in dense stands are very likely to result in serious windfall unless the situation is well protected. For this reason the leaving of seed trees, either alone or in small groups, seldom works satisfactorily. On the more exposed situations, with shallow or wet soil, even unthinned

stands may be blown down. As a rule, however, solid stands, even when overdense, are windfirm, provided they are of sufficient extent—not narrower than the height of the trees. Light or even heavy thinnings can usually be made without danger of windfall by conforming the operation to the height, age, and density of the stand, the character of the soil, and the exposure.

Haphazard thinnings made on the Deerlodge Forest from 13 to 25 years ago in the course of ordinary lumbering operations show a remarkably small amount of windfall. On only 2 of the 18 blocks examined was any windfall evident, and in each of these cases the stand had been very heavily thinned by the removal of 82 per cent of the original number of trees and 66 per cent of the cubic volume. On the remainder of the areas the stand was not so heavily thinned, though the cutting was heavier than would be considered advisable in present-day Forest Service timber sales. In one of the early Forest Service sales on the Deerlodge Forest, on an area partly exposed and partly protected from the wind, where the soil was deep, fresh, and firm, a selection cutting removed about 40 per cent of the total number of trees and 59 per cent of the cubic volume. In the five years following the cutting only 3 trees out of the approximately 5,000 left blew down. All of these were on the exposed portion of the sale area, and in each case a defective root system, due to fire injury, was the main cause of the fall. These and other observations indicate the importance of removing trees with defective root systems.

Another climatic factor which may cause damage to individual seed trees is sun scald. In many cases seed trees which have withstood the wind for a number of years have died apparently as a result of too great exposure to sun. Owing to the thin bark of lodgepole the cambium on the insolated side of the tree is killed first. Many of the trees crack open on the sunward side before they die. The drying out of the ground when it is exposed to the sun probably helps to kill such trees. If trees are left so that their trunks do not receive full sun during most of the day, the likelihood of damage from sun scald is very small.

Frost cracks sometimes appear in lodgepole pine, and when they take a spiral form lessen the value of the tree for saw timber. Strong winds sometimes open these cracks in a way to form large seams or checks which afford ready entrance for insects and fungi. The damage appears to be more prevalent in overmature than in younger stands, and is more often encountered in Wyoming and Colorado than in Montana. Frost may also cause injury by heaving 1 or 2 year old seedlings out of the ground.

Snow, accumulating on the tops of lodgepole trees 4 inches or less in diameter, especially when in dense stands, often bends the

FIG. 1.—LODGEPOLE SEEDLINGS INJURED BY SMELTER SMOKE. IN "ACUTE" STAGE.

Note the scant foliage, only that of the current year. Decreasing rate of height growth in last few years shown by shorter distance between whorls of branches. Taken 9 miles in an air line from the smelter.

FIG. 2.—LODGEPOLE SEEDLING DAMAGED BY "RED BELT," BUT SINCE RECOVERED.

The damage occurred three growing seasons before the picture was made. Note luxuriant foliage on last three years' growth as compared with smelter-injured trees. Also that all of the leaves more than three years old have dropped from the stem.

poles to the ground or breaks them off at a height of from 10 to 20 feet. Snow-break may be beneficial in overdense stands which are in need of thinning, but may also do considerable damage in thinned stands where the individual trees can no longer rely on their neighbors for support.

The so-called "red belt" injury is manifested by the sudden reddening and subsequent death of practically all the needles on the exposed portions of the trees in a well-defined altitudinal belt. Some are killed outright, though usually the buds remain uninjured and the trees later recover, in some cases after complete defoliation. The most extensive damage of this nature on record occurred in January, 1909, when large areas were affected in the Black Hills and throughout the Rocky Mountains from Montana to Colorado. The belt was generally from 200 to 400 feet in width between elevations of 6,500 and 7,000 feet in the lodgepole region, and at lower elevations in the northwestern portion of Montana. Trees on all aspects were affected, but the greatest damage was done on southerly slopes and in situations exposed to the wind. The injury resulted from unusual weather conditions during the winter. In 1909 it was caused by a chinook of several days, when the ground was frozen and covered with snow. The air was quite warm and the sun very hot, especially when reflected from the surface of the snow, causing the leaves of the trees to transpire all of their available moisture. Since the roots were frozen and additional moisture could not be obtained from the ground, the leaves withered, and in some cases the buds also dried out excessively. The most satisfactory explanation of the occurrence of the injury in an altitudinal belt is that early in the winter, before the ground froze, snow fell at the higher elevations above the zone of injury. Later the ground in the belt froze solid, but not the ground in the zone below it nor that in the zone above it. Later still the entire area was covered by a heavy fall of snow. In this way the belt was the only part of the region in which the ground was solidly frozen and no soil moisture was available to replace the water transpired by the leaves.

Hedgcock grouped the species of the lodgepole region in respect to their susceptibility to this injury as follows, naming the most susceptible first:

Yellow pine.
Douglas fir.
Lodgepole pine.
Limber pine.
Engelmann spruce.
Alpine fir.
Juniper.

Douglas fir unquestionably suffered more than did lodgepole on areas where the greatest damage occurred. Many Douglas fir

trees were killed outright, while even those lodgepoles which had their leaves killed retained their buds and put out new leaves the following spring. Lodgepole saplings affected in 1909 now present a peculiar banded appearance, that part of the stem which was above the snow at the time of the injury being bare of leaves, while that part below it, which was covered by snow, and that part above it, which has grown since, are green.

The red belt injury has sometimes been confused with damage from smelter fumes, but its nature is entirely different. (Pl. V, fig. 2.) Trees killed by the former die quickly as compared with those killed by the fumes. Weather-damaged trees which have recovered show a quick resumption of normal growth rate and a general healthy appearance, a marked contrast to the trees suffering from the smoke fumes.

ANIMALS.

Porcupines damage lodgepole to some extent by gnawing the bark in order to get at the tender cambium. They confine their efforts chiefly to young or middle-aged trees, though trees as large as 18 inches in diameter have been found completely girdled. Usually the bark is gnawed near the base of the tree, but occasionally animals work in the tops, as high as 50 or 60 feet from the ground, causing the trees to become stag-headed. Small branches are sometimes girdled near their junction with the main stem. Sometimes the attack may result in a beneficial thinning in an overdense stand, but porcupines have done considerable damage to trees on the Routt National Forest, Colo., where more than half of the trees on areas from one to several acres have been girdled, and in several localities on the Bonneville National Forest, Wyo., where 25 per cent of the trees have been injured.

Rabbits often bite through the main stem of young seedlings, particularly the slender ones in overdense stands. Squirrels may cause a slight decrease in the rate of growth by biting off a number of the cone-bearing twigs. They also eat considerable quantities of seed, the result of which may be harmful in places where reproduction is not up to the required density. Sheep grazing unrestricted may damage seedlings and very young growth by trampling.

ASSOCIATED SPECIES.

Over most of its range lodgepole pine occurs in almost pure stands. Other species, however, often grow in mixture with it, particularly at the upper and lower altitudinal limits of the lodgepole zone. At the lower limit its chief associate is Douglas fir, which tends to take possession of areas too dry for lodgepole. Fir reproduction often occurs under the latter, and many areas now covered with lodgepole

would doubtless long since have given way to the more tolerant fir had it not been for recurrent fires. On south slopes and on dry, rocky knolls and ridge tops the fir may extend almost to the upper limits of the lodgepole belt. At the upper limit of the zone the chief associates of lodgepole are Engelmann spruce and Alpine fir, which come in on the moister sites. Spruce sometimes follows stream courses far down into the lodgepole type, where it takes possession of the moist bottomlands. Both the fir and spruce are much more tolerant than lodgepole, and reproduce under dense shade. At the higher elevations Alpine fir is apt to be more abundant in reproduction than spruce, but the latter is a longer-lived tree and of much greater importance in mature stands. Both species when growing with lodgepole assist to a large extent in pruning the latter of its side branches.

In Colorado and Wyoming limber pine and aspen also grow with lodgepole, though to a rather limited extent. In Montana whitebark pine is usually mixed with lodgepole toward the latter's upper limit.

PERMANENCY OF LODGEPOLE TYPE.

Many of the present stands of lodgepole undoubtedly occupy areas previously covered with other species which have been driven out by repeated fires. If fire were kept entirely out of the forests, therefore, the lodgepole would in many situations be replaced by the original species—at the lower altitudes by Douglas fir, at the upper ones by Engelmann spruce and Alpine fir. All of these species are more tolerant than lodgepole, and for this reason are able to crowd it out on sites adapted to all of them. It is likely, however, that there is a middle belt considerably narrower than the present lodgepole zone where conditions of soil and climate are more favorable to it than to competing species, and where it would probably be able to form a permanent type.

In connection with the ability of lodgepole to maintain itself in competition with other species, it is interesting to know that Knowlton, in his studies of the paleobotany of Yellowstone Park, found in Tertiary deposits a serotinous cone of a tree species which he named *Pinus premurrayana*,[1] because he considered it the immediate ancestor of the lodgepole of to-day. A fossil cone, perfectly preserved, is slightly longer and narrower than typical lodgepole cones of the present. In Yellowstone Park Knowlton also found the fossil remains of species of *Sequoia*, *Juglans*, *Hicoria*, *Fagus*, *Castanea*, *Ficus*, *Magnolia*, etc. Of all the species now present in the park lodgepole is the sole survivor from the Tertiary age.

[1] The form of lodgepole pine occurring in the Rocky Mountains, now known as *Pinus contorta*, has also been known as *Pinus contorta*, var. *murrayana*, and as *Pinus murrayana*.

GROUND COVER.

Lodgepole stands, particularly in Montana and northern Wyoming, have a ground cover of grasses and weeds, many of which are valuable as forage. These include pine grass (*Calamagrostis rubescens*) in very large amounts, timber oats grass (*Danthonia intermedia*), lupine (*Lupinus serviceus*), fireweed (*Chamaenarion augustifolium*), Indian paintbrush (*Castilleja chromosa*), etc. Other plants worthless for forage include huckleberry (*Vaccinium scoparium*), which is especially abundant on the poorer sites, arnica (*Arnica cordifolia*), and elk grass (*Xerophyllum tenax*). In moist places alder (*Alnus tenuifolia*) and willow frequently occur as underbrush. The forage plants are less abundant in Colorado and southern Wyoming and the huckleberry more prevalent. Ordinarily fallen leaves disintegrate so rapidly that there is no accumulation of duff from this source. In mature stands there is very little litter as a rule, and one can ride through them almost anywhere.

AGE CLASSES.

A striking characteristic of lodgepole-pine forests is their even age. This, of course, is due to the fact that most of the present stands have originated as a result of fire, followed almost immediately by reproduction. As a rule, the burned areas thoroughly stock in a few years, though sometimes the reproduction is very open, the blanks filling in slowly with young growth and so producing an uneven-aged stand. Young stands often contain a few older trees, most of them limby and fire-scarred at the base, which have managed to escape destruction.

Clear cutting is usually followed by even-aged stands, though the reproduction is apt to be slightly slower in establishing itself, particularly if fire is kept out. Some areas cut over 20 years ago now have their blanks filled from seed produced by the rather scattered reproduction which followed the cutting.

All the trees in even-aged lodgepole forests are not necessarily of the same size. Unless the stand is so dense as to cause stagnation some seedlings, especially on the more favorable sites, get a better start and develop more rapidly than others. A small, suppressed tree often may be as old as another more vigorous one at its side two or three times as large in diameter.

Fires have been so frequent in the region that they have brought about a wide range of age classes in the lodgepole zone as a whole. In Montana most of the stands are comparatively young. Figures collected there show that approximately two-thirds of the timbered area is now covered with nonmerchantable, immature growth, while the merchantable timber on the remaining third is partly immature,

partly mature, and partly overmature. In Wyoming and Colorado there is a much larger proportion of mature, and especially overmature, lodgepole stands, a difference which leads to the conclusion that in the past fire has been less prevalent in Colorado and Wyoming than in Montana.

YIELD.

FACTORS INFLUENCING YIELD.

The yield per acre of any stand varies with its age, density, and the quality of the site on which it grows. Ordinarily the better sites and older stands produce the heaviest yields, provided deterioration has not set in. With lodgepole, however, the yield, particularly in board feet, is determined more by the density of the stand than by either its age or the quality of the site. It is not unusual to find young, properly stocked stands of lodgepole with larger yields than older, overstocked stands on better sites. The effect of density on yield is illustrated in Table 6, which gives the results of measurements of 10 sample plots, all of approximately the same age.

TABLE 6.—*Effect of density on yield per acre of lodgepole pine, Deerlodge National Forest, Mont.*

Sample plot.	Age.	Trees per acre.		Yield.			Ratio of board feet, 6 inches top diameter, to cubic feet.	Height of average tree (dbh. 8 in.).	Diameter of average tree.	
		Entire stand.	Main stand.[1]	Total.	Scale timber, top diameter, inside bark, to— 6 inches.	Scale timber, top diameter, inside bark, to— 8 inches.			All trees.	Main stand.[1]
	Years.	*No.*	*No.*	*Cu. ft.*	*Bd. ft.*	*Bd. ft.*		*Feet.*	*Inches.*	*Inches.*
1	110	501	293	4,187	10,542	3,217	2.52	59	7.2	8.4
2	109	701	325	5,441	8,682	1,580	1.60	67	6.5	8.1
3	109	764	338	6,286	19,440	4,387	3.09	71	6.6	8.4
4	108	810	338	7,331	20,400	2,456	2.78	72	6.6	8.6
5	107	960	250	5,614	15,260	1,190	2.72	69	5.7	7.9
6	107	987	303	6,178	12,070	1,610	1.95	69	5.9	7.8
7	107	1,249	149	5,080	2,980	....	.59	67	5.0	7.5
8	104	1,495	124	4,840	2,480	....	.51	57	4.7	7.3
9	101	1,564	124	4,668	2,480	....	.53	58	4.6	7.5
10	105	1,805	73	4,405	1,460	....	.33	57	4.2	7.4

[1] Includes all trees 7 inches and over in diameter, breast high.

The table shows that an increase in the number of trees per acre beyond a certain point results in a marked decrease in the number of trees which will make scale timber, in the average diameter and height, and in the yield, especially in board feet. Much denser stands existed than any of those shown in the table, with correspondingly smaller yields. One plot 160 years old, for example, contained approximately 3,500 live trees per acre, not more than 4 inches in diameter. Such a stand produces only lagging poles. Other stands of the same age are still denser, producing nothing of value.

AVERAGE AND MAXIMUM STANDS.

Reconnaissance estimates covering 65,000 acres on the Deerlodge National Forest, which may be considered as fairly representative of the lodgepole region in Montana, show that the average stand of merchantable timber for all ages, densities, and sites is approximately 5,564 board feet per acre.[1] In Wyoming and Colorado the average stand of merchantable timber is estimated to run from 5,000 to 8,000 board feet per acre. Average stands on timber sale areas are apt to run much higher than this, because they usually consist of the better timber, and also because the reconnaissance figures apply to a considerable amount of cut-over land and to areas covered with young growth that is barely merchantable. Average stands actually found on timber-sale areas on the different National Forests are shown in Table 7.

TABLE 7.—*Average stand per acre of lodgepole pine and associated species on timber-sale areas in Colorado, Wyoming, and Montana.*

National Forest.	Yield per acre.		
	Lodgepole.	Other species.	Total.
	Bd. ft.	*Bd. ft.*	*Bd. ft.*
Arapaho, Colo	19,410	....	19,410
Cochetopa, Colo	6,880	900	7,780
Gunnison, Colo	2,500	925	3,425
Medicine Bow, Wyo	14,225	....	14,225
Hayden, Wyo	8,884	....	8,884
Bighorn, Wyo	8,300	....	8,300
Bridger, Wyo	2,771	2,571	5,342
Deerlodge, Mont	14,318	....	14,318

While the stands on the Arapaho, Medicine Bow, and Deerlodge National Forests are considerably better than the average, they are not as heavy as the stands sometimes found on limited areas in virgin forests. Five of the heaviest stands yet measured contained the following amounts of lodgepole, together with small quantities of Engelmann spruce, Alpine fir, and Douglas fir:

National Forest:	Board feet per acre.
Arapaho, Colo	27,791
Routt, Colo	24,400
White River, Colo	36,335
Medicine Bow, Wyo	34,512
Deerlodge, Mont	35,935

In addition to the 35,935 feet of green lodgepole pine, the stand on the Deerlodge Forest, which was 200 years old, also contained 4,610 feet of Englemann spruce and Alpine fir, and 8,090 feet of dead lodgepole, a total for live and dead timber of 48,635 board feet per acre.

[1] All stands were considered merchantable which contained 2,000 board feet per acre or more, based on a minimum log 16 feet long and 6 inches in diameter at the smaller end. Many 7-inch lodgepole trees will yield such a log.

DENSELY STOCKED STANDS.

Table 8 shows the yield of stands which are densely stocked, but not so crowded as to cause stagnation of growth. The figures were obtained on the Deerlodge National Forest on the best quality of site. Most of the sample areas measured were 1 acre each.

Table 8.—*Average yield per acre of densely stocked stands of lodgepole pine at different ages on the best sites (Quality I), Deerlodge National Forest, Mont.*

Age in years.	Basal area, square feet.	Trees per acre.		Average diameter, main stand.	Average height, main stand.	Yield.		Annual growth.			
		Entire stand.[1]	Main stand.[2]					Mean.	Periodic.	Mean.	Periodic.
	No.	*No.*	*No.*	*Inches.*	*Feet.*	*Cu. ft.*	*Bd. ft.*[3]	*Cu. ft.*	*Cu. ft.*	*Bd. ft.*	*Bd. ft.*
40	106	1,550	50	7.0	36	1,400	....	35	....	....	....
50	128	1,250	175	7.5	46	2,250	....	45	85	....	....
60	144	1,000	225	7.7	56	3,100	4,800	52	85	80	....
70	156	825	255	8.1	60	3,800	6,200	54.3	70	89	140
80	166	725	280	8.5	64	4,350	7,500	54.4	55	94	130
90	174	650	300	8.8	66	4,900	9,000	54.5	55	100	150
100	180	600	320	9.0	68	5,400	10,800	54	50	108	180
110	184	535	330	9.4	70	5,800	12,600	53	40	115	180
120	188	500	345	9.6	72	6,200	14,800	52	40	123	220
130	192	460	350	10.0	74	6,550	17,200	50	35	132	240
140	194	430	355	10.3	75	6,850	19,800	49	30	141	260
150	196	415	360	10.5	76	7,150	22,200	48	30	148	240
160	198	400	370	10.6	77	7,400	25,000	46	25	156	280

[1] Includes all trees 3 inches and over in diameter, breast high.
[2] Includes all trees 7 inches and over in diameter, breast high.
[3] To a 6-inch top diameter limit.

NORMAL STANDS.

Normal stands are those which at maturity give the maximum yield possible to obtain under a given method on a given quality site. In the case of lodgepole pine properly or normally stocked stands are rare. Reconnaissance data, covering many thousands of acres of young growth in Montana, show that nearly 80 per cent of the area is overstocked, and that on the average the young growth is from one-half to six-tenths normally stocked. Because of its slow mortality lodgepole must start in comparatively open stands in order to yield the maximum amount of merchantable material at maturity. Such stands, however, are not dense enough to insure rapid, natural pruning. As already pointed out, the number of trees per acre adopted as the criterion of normality is 1,000 at 10 years, 500 at 30 years, 300 at 90 years, and 250 at 140 years. With these figures as a guide, and taking into account the total yield of the stand, Table 9 has been constructed from the figures obtained from those plots in Table 8 on which the stocking appeared to be most nearly normal. The amount of data is not sufficient to make the table anything more than indicative of what may be expected from normal stands of different ages on the best and on average sites. The original figures were secured on quality I sites, and the yields for quality II sites have been derived by

multiplying the yields for quality I sites by 60 per cent, which seemed a fair reducing factor. In the case of board-foot yields strictly accurate results are not obtained when the same reducing factor is used for all ages and stands. The method is, however, sufficiently accurate to result in figures which indicate in a general way what results may be expected.

TABLE 9.—*Average yield per acre of normal stands of lodgepole pine at different ages, Deerlodge National Forest, Mont.*

BEST SITES—QUALITY I.

Age in years.	Yield.			Annual growth.					
	Cubic feet.	Board feet scaling in top to—		Cubic feet.		Board feet scaling in top to—			
		6 inches.	8 inches.	Mean.	Periodic.	6 inches.		8 inches.	
						Mean.	Periodic.	Mean.	Periodic.
10	150			15	15.0				
20	450			22	30.0				
30	950	900		32	50.0	30	90		
40	1,900	3,200		47	95.0	80	230		
50	3,050	5,600		61	115.0	112	240		
60	4,000	8,100		67	95.0	135	250		
70	4,900	10,700		70	90.0	153	260		
80	5,600	13,400		70	70.0	167	270		
90	6,300	15,800		70	70.0	176	240		
100	6,800	18,200	2,500	68	50.0	182	240	25	25[illegible]
110	7,200	20,500	5,000	65	40.0	186	230	45	25[illegible]
120	7,450	22,700	7,600	62	25.0	189	220	63	26[illegible]
130	7,600	24,600	10,700	58	15.0	190	190	82	31[illegible]
140	7,750	26,400	14,000	55	15.0	189	180	100	33[illegible]
150	7,850	28,200	17,300	52	10.0	188	180	115	33[illegible]
160	7,900	29,800	20,400	49	5.0	186	160	127	31[illegible]
170	7,925	31,200	23,300	47	2.5	184	140	137	29[illegible]
180	7,950	32,600	25,800	44	2.5	181	140	143	25[illegible]
190	7,975	33,600	28,000	42	2.5	177	100	147	22[illegible]
200	8,000	34,600	30,000	40	2.5	173	100	150	20[illegible]
210	8,025	35,600	31,500	39	2.5	170	100	150	15[illegible]
220	8,050	36,600	32,800	37	2.5	166	100	149	13[illegible]

AVERAGE SITES—QUALITY II.

Age in years.	Yield.		Annual growth.				Ratio of board feet to cubic feet
			Mean.	Periodic.	Mean.	Periodic.	
	Cu. ft.	*Bd. ft.*[1]	*Cu. ft.*	*Cu. ft.*	*Bd. ft.*	*Bd. ft.*	
10	90		9	9			
20	270		13	18			
30	570	540	19	30	18	54	0.9[illegible]
40	1,140	1,920	28	57	48	138	1.6[illegible]
50	1,830	3,360	37	69	67	144	1.8[illegible]
60	2,400	4,860	40	57	81	150	2.0[illegible]
70	2,940	6,420	42	54	92	156	2.1[illegible]
80	3,360	8,040	42	42	100	162	2.3[illegible]
90	3,780	9,480	42	42	105	141	2.51
100	4,080	10,920	41	30	109	144	2.6[illegible]
110	4,320	12,300	39	24	112	138	2.8[illegible]
120	4,470	13,620	37	15	113	132	3.0[illegible]
130	4,560	14,760	35	9	114	114	3.2[illegible]
140	4,650	15,840	33	9	113	108	3.41
150	4,710	16,920	31	6	113	108	3.6[illegible]
160	4,740	17,880	30	3	112	96	3.7[illegible]

[1] Board feet scaled to 6 inches in the top.

It should be noted that these normal yields represent the best that have been found in unmanaged virgin forests, not the best which it is theoretically possible to obtain under proper methods of forest management. Table 2, for example, shows that a dominant tree at the age of 140 years is able to reach a diameter of about 12 inches and a height of about 75 feet, with a volume of 120 board feet. To determine in an approximate way how many trees could be produced per acre with the right kind of thinnings at proper intervals, the average space in the stand occupied by a tree of this size was measured in a number of instances and found to average approximately 166 square feet. At this rate there should be 262 such trees per acre, with a yield of 31,400 board feet, which is 19 per cent greater than that given in the table of normal yield for 140-year-old stands on the best sites. While it is probable that such a yield could seldom be obtained even under intensive management, the illustration serves to show the possibility of securing better results with improved spacing.

EFFECT OF THINNING.

The marked effect which thinnings often have in increasing the rate of growth of individual trees is also notable in the case of stands. This effect is seen in a number of cut-over areas on the Deerlodge Forest which were culled from 13 to 25 years ago. In every case the loggers removed only such timber as suited their purpose, in some cases taking the larger material for ties, in others, removing the smaller trees for fence posts. Some of the trees left had thrifty crowns, and for this reason could be expected to benefit from the increased light; while others were very badly suppressed, with small crowns, and could hardly be expected to accelerate their growth to any extent. In collecting the data summarized in Table 10, average trees were selected for measurement irrespective of the probability of their showing an increase in the rate of growth. The various periods which had elapsed since the different cuttings were made averaged 20 years, and for purposes of comparison the figures were all worked up on the assumption that the cutting was done just 20 years before the date of the investigation.

TABLE 10.—*Effect of thinning on yield per acre of lodgepole pine in individual sample plots on the Deerlodge National Forest, Mont.*

PLOTS SHOWING NO INCREASE IN RATE OF GROWTH.

Age at time of thinning in years.	Period since thinning in years.	Stand 20 years ago.								Periodic annual growth (for 20 years) of trees left.		Increase or decrease in rate of growth after thinning.
		Trees.			Volume.			Average diameter.				
		Total.	Cut.	Left.	Total.	Cut.	Left.	Cut.	Left.	Before thinning.	After thinning.	
		Number.	*Number.*	*Number.*	*Cu.ft.*	*Cu.ft.*	*Cu.ft.*	*Inches.*	*Inches.*	*Cu.ft.*	*Cu.ft.*	*Per cent.*
48	18	550	290	260	1,955	521	1,434	4.3	6.1	45.5	15.6	−66
49	18	430	320	110	2,336	1,486	850	5.9	6.7	27.0	19.8	−27
106	14	1,600	1,200	400	6,136	3,396	2,740	4.5	6.2	34.0	27.7	−19
108	20	690	290	400	3,339	1,594	1,755	6.0	6.1	17.2	4.7	−73
123	20	1,730	1,120	610	2,267	1,028	1,239	3.2	4.3	12.1	8.1	−33

PLOTS SHOWING INCREASE IN RATE OF GROWTH.

44	20	570	280	290	951	399	552	4.2	4.1	16.1	22.6	40
44	15	650	420	230	1,305	697	608	4.2	4.4	21.6	30.4	40
45	15	910	500	410	1,434	563	871	3.5	4.2	31.8	36.3	14
95	14	930	730	200	3,146	2,316	830	4.9	5.3	6.2	17.5	182
95	20	1,050	500	550	2,049	985	1,064	4.3	3.7	15.0	33.1	121
95	25	940	610	330	2,412	1,058	1,354	4.1	5.2	13.7	24.7	80
100	25	980	770	210	2,454	1,430	1,024	4.1	5.6	8.2	21.3	160
119	20	580	470	110	2,216	1,335	881	5.5	6.5	10.1	15.1	50
125	20	1,030	680	350	2,921	1,600	1,321	4.4	4.9	14.3	19.1	34
127	20	520	270	250	3,443	1,388	2,055	5.7	6.7	15.9	21.4	35
141	13	840	490	350	5,178	2,887	2,291	6.0	5.9	15.9	28.8	81
151	24	440	176	264	4,459	2,286	2,173	8.9	6.9	9.5	29.2	207
154	24	585	485	100	3,769	2,609	1,160	6.1	8.1	5.5	10.5	91

Of the 18 plots measured, 13, or 72 per cent, showed an increase in the rate of growth after the thinning. In other words, the small number of trees left after thinning produced more cubic feet of wood per acre than would have been produced by the entire stand had it been left unthinned and continued to grow at the same rate as before the thinning. This result is particularly remarkable when it is remembered that all of the plots had reached an age when the periodic rate of growth would ordinarily be decreasing. Table 9 shows that in normally stocked stands the periodic rate of growth in cubic feet increases rapidly up to 50 years, after which it decreases slowly. For this reason the falling off in the growth of the 106 and 123 year old plots is no greater than would be the case in unthinned stands of the same age, and very likely it is even less. The apparently abnormal rate of decrease in the rate of growth of the 48 and 49 year old plots is probably due to the fact that they were nearly normal at the time of cutting, as indicated by their volume, with the result that the rather heavy thining had an injurious effect upon the trees left. The 108-year-old plot is the only one for which the marked decrease in rate of growth can not be satisfactorily explained.

If areas logged without thought for the future show such results, it is reasonable to suppose that thinnings made with the object of improving the stand will result even more satisfactorily, for the trees left will be thrifty-crowned specimens of moderate size, which are best able to take advantage of the increased light. Next to the exclusion of fire, the most important respect in which systematic management will improve the growth and yield of lodgepole forests is in bringing the stands to a density more nearly normal.

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(PROFESSIONAL PAPER.)

WOOD PIPE FOR CONVEYING WATER FOR IRRIGATION.

By S. O. Jayne, *Irrigation Manager.*

INTRODUCTION.

During the period subsequent to 1880, the manufacture of wood pipe has grown to be an industry of considerable magnitude, and the use of such pipe is a matter of economic importance. On the part of many there has been some skepticism as to the merits of wood for water conduits. On the other hand, there are those who have had too much confidence in it. As a consequence, the value of wood pipe has often not been adequately appreciated, while in other instances it has been overrated. Many points upon which opinions differed at the beginning could be settled only upon the evidence of time and experience. Such experience, extending over a period of more than 30 years, affords a great deal of information bearing upon various points which have been and are still to some extent debatable.

The facts relating to the use of wood pipe and practice in its construction and operation during this period should, if gathered together and carefully analyzed, be sufficient to settle most of the disputed points and establish its status beyond further serious question. That there is need of such information is evident. The capital already invested in wood-pipe lines throughout the United States amounts to many millions of dollars, and this amount is being increased annually. Protection of present investments, therefore, demands that existing pipe lines be maintained and operated in accordance with what experience has shown to be the practice most favorable to long life; and future investments should be safeguarded by and profit from all available knowledge bearing upon the design, location, and maintenance of such pipe lines.

That advantage of available knowledge has not in every instance been taken may be seen by inspection of much recent work. This has doubtless been due largely to the difficulty of obtaining desired

Note.—This bulletin will be of interest to irrigation engineers, owners of irrigation works, water power companies, and water departments of municipalities.

information and in part to carelessness or bad judgment. In connection with irrigation projects many expensive wood-pipe lines have been built, perhaps according to good design and careful location, and then turned over to operatives who have no knowledge of how to maintain them properly. For this reason it is especially important to the irrigation interests of the West that such knowledge be made readily available.

Recent investigations have included the inspection of many pipe lines throughout several Western States; interviews and correspondence with manufacturers, builders, and operators of wood pipe; and a review of published data bearing upon the subject. It is believed that the findings should be helpful in arriving at a proper estimate of the possibilities as well as the limitations of wood pipe for several classes of service; that they should be of special value to all who are interested in the construction or maintenance of irrigation projects. The presentation of such findings, in the hope that the foregoing may be true, is the purpose of this bulletin. For much of the information acknowledgment is due to many engineers, managers of waterworks, irrigation systems, power companies, and pipe factories, to all of whom the writer wishes to express appreciation and thanks.

HISTORY.

The first use of wood for water pipe appears to have been several centuries ago. It is said that 400 miles of "pump logs" were laid in London in 1613, and it is known that the use of wood pipe for municipal waterworks was common in eastern cities of this country more than 100 years ago.

The primitive wood pipe was usually of elm, pine, spruce, or other soft wood which was easily bored, and the holes seldom exceeded 6 inches in diameter, though it is said that at Philadelphia oak logs up to 3 feet in diameter were used with bores of from 6 to 12 inches. The logs were cut into lengths up to 12 feet. Boring was done by hand.[1] This primitive type of pipe has been made in places within quite recent years, but its manufacture declined rapidly after 1820 with the almost universal adoption of cast-iron pipe which, by new processes, could be made in sizes much larger than the wood pipe of that time.

In 1885, A. Wyckoff, of Elmira, N. Y., patented a boring machine for making pipe from solid logs. The product of his factory and of others using the machines secured gradual recognition, first locally, and later somewhat generally, in the mining districts of Pennsylvania and elsewhere, for use under conditions where acids injurious to cast iron and steel were encountered. But the notable revival in

[1] U. S. Geol. Survey, Water Supply and Irrig. Paper 43, p. 63.

the use of wood pipe began about 1880 with the construction, according to new ideas, of what has come to be known as continuous stave pipe. The construction of continuous stave pipe was soon followed by the manufacture of stave pipe in sections and improved bore pipe, both of which have come to be known as machine-banded pipe. Continuous stave pipe and machine-banded pipe are both very extensively manufactured and used at the present time. These two types of pipe will be considered in this bulletin.

CONTINUOUS STAVE PIPE.

This type of pipe is a development of the old stave penstocks, many of which were built in the New England States, New York, and Eastern Canada from 1850 to 1870.[1] These were usually made in tapered sections, banded with flat iron bands. The sections were joined by inserting the small end of one a few inches into the large end of another. Such joints were faulty, which fact led to building pipe in which the ends of staves butted together, thus forming continuous stave pipe. This form of construction appears to have been first used in 1874.[2] The first extensive use, however, followed the construction of pipes designed and built by C. P. Allen, at Denver, Colo., about 1884.

Except in minor details, continuous stave pipe of the present day is the same as that built by Mr. Allen in the early eighties. It is essentially pipe built continuously in place, of staves having radial edges and faces milled to form arcs of concentric circles, the inner circle being of radius equal to half the nominal diameter of the pipe. The staves are held together by round steel bands secured by shoes and nuts, and the butt joints are made tight by the insertion of thin steel clips which fit into saw kerfs across the ends of the staves. This form of construction is illustrated in Plate I.

ADAPTABILITY AND USE OF CONTINUOUS STAVE PIPE.

Continuous stave pipe is adapted to the usual service required in conveying water long distances for municipal, power, irrigation, mining, or manufacturing purposes. It has a particularly wide field of usefulness throughout the West because of the low cost and ease with which the material for its construction can be procured, transported, and assembled in regions remote from railroads and difficult of access, where the expense of cast iron or other kinds of pipe commonly used in the East would in many instances prohibit their use.

In addition to its low first cost, experience has shown that wood pipe has other advantages as compared to cast-iron or steel pipe. It

[1] U. S. Geol. Survey, Water Supply and Irrig. Paper 43, p. 63.
[2] Trans. Amer. Soc. Civ. Engin. (1877), p. 69.

is not so subject to injury from freezing, settling, or expansion and contraction due to extremes of temperature, while if injury is sustained, extra material can usually be obtained readily, and repairs can be made much more quickly and with less expense than would be required for pipes of iron or steel. Furthermore, the capacity of wood pipe is probably somewhat greater than that of iron or steel of equal size, and may, under favorable conditions, increase with time instead of being reduced by tubercles and corrosion such as occur in the other kinds of pipe mentioned.

More continuous stave pipe has been used for conveying municipal water supplies than for any other purpose. The Denver Union Water Co. has been using it since 1884, and now has upwards of a hundred miles installed. Seattle has over 50 miles; Tacoma completed about 43 miles in 1912 and has built more since that time; the Butte City Water Co., prior to 1899, had installed about 30 miles; Walla Walla, Wash., has 13 miles. It is used to some extent at Astoria, Oreg.; Salt Lake City, Ogden, and Provo, Utah; Canon City, Pueblo, Loveland, Trinidad, and Fort Collins, Colo.; and in many other places in the West that might be mentioned, as well as at a few in the Atlantic States.

The use of this type of pipe in connection with power development, though as yet perhaps not so extensive, is coming to be even more general than for conveying municipal water supplies, and examples might be enumerated by the hundred of pipes in sizes from 2 feet to 14 feet in diameter that have been installed for this purpose throughout the United States, Canada, Mexico, and Alaska.

The use of wood pipe for irrigation purposes is confined to the Western States, but there are few of the more important irrigation projects of recent development on which it is not employed at least to some extent, its chief adaptability being for "inverted siphons" for carrying water across deep ravines or depressions not otherwise easily spanned. In a few instances the original gravity ditches have been entirely supplanted by continuous stave pipe. It is also very frequently used for conducting water from pumps to the points of discharge into ditches or reservoirs at higher elevations.

Continuous stave pipe has, as a rule, been restricted to service where the pressure head does not exceed 200 feet, though in many instances short sections are required to carry greater pressures rather than change to another type of pipe. A few pipes of this kind have been built for heads up to 400 feet.

DESIGNING OF CONTINUOUS STAVE PIPE LINES AND MATERIALS USED IN CONSTRUCTION.

A discussion of the theory underlying the many considerations of the economic design of wood-pipe lines is not within the scope or

purpose of this bulletin. Such discussion may be found in published transactions of engineering societies and in engineering journals. But some points relative to practice in design and use of materials will be given in the following pages.

SIZE OF PIPE.

Continuous stave pipes have been built in sizes from 10 inches in diameter up to 13.5 feet, but this form of construction is not common at present in pipes of diameter less than 20 inches. Pipes smaller than this are usually machine banded. Sizes greater than 8 feet in diameter are exceptional. The size of pipe to use in any particular place must be governed by conditions. For gravity lines the quantity of water to be carried and the available head are the controlling factors. If for conducting water from pumps, the size must be determined with reference to the economic relation between velocity or permissible friction head and power requirements. A pipe which is too small may involve an excessive expense for power, while too large a pipe would require initial investment greater than necessary.

The capacity of wood pipe is generally computed according to Kutter's formula, in which a value of "n," the coefficient of roughness, is selected somewhere between 0.010 and 0.013, depending upon conditions and the judgment of the engineer. Just what value of "n" to assume is a debatable question. Experiments are now being made to determine the carrying capacities of wood pipes and the proper coefficient of roughness to apply in such formulas as Kutter's.

As a result of measurements of flow in pipes, the following values for "n" for specific cases have been determined by various writers: Schuyler, 30-inch pipe, 0.0096; Gutelius, 24-inch pipe, 0.01; Adams, 18-inch pipe, 0.01; Adams, 14-inch pipe, 0.011; Marx, Wing, and Hoskins, 72-inch pipe, 0.012 to 0.015. Smaller values for "n" are usually assumed for small pipes than for larger ones, and there appears to be reason for believing that "n" may vary also with velocity. Moritz,[1] from measurements of pipes 4 inches to 55 inches in diameter, found $V=1.72\ D^{0.7}\ H^{0.555}$ and $Q=1.35\ D^{2.7}\ H^{0.555}$, where Q=discharge in second-feet; V, the mean velocity of flow in feet per second; D, diameter of pipe in feet; and H, friction loss per 1,000 feet of pipe.

Based either on Kutter's formula or on one of the exponential type, various tables have been prepared for convenient use in estimating the capacity of pipes, loss of head in friction, etc. Such tables may be obtained from the leading manufacturers of wood pipe.

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[1] Engin. News, 68 (1913), No. 24, p. 668.

STAVES.

In designing staves economy dictates that the width and thickness be made such that stock lumber of standard sizes may be used. These are 2 by 4 inches, 2 by 6 inches, 3 by 6 inches, 4 by 6 inches, and 4 by 8 inches. Without strict adherence to the finer theoretical considerations as to thickness, etc., staves for most pipes for ordinary heads, and from 22 inches to 44 inches diameter are milled from 2 by 6 inch stock, finished 1⅝ inches in net thickness. From this up to 60 inches staves 2 inches thick are commonly used, and in some instances for pipes 72 inches in diameter. For pipes from 5 to 8 feet in diameter staves are usually 2½ inches thick. For pipes to withstand extremely high pressure and for those of extremely large size the thickness of the staves should be increased accordingly, in order to insure safety against crushing or shear of the wood due to the greater tightness of cinching required. The width will be such as to cut with least waste from the stock sizes of lumber.

Western yellow pine (*Pinus ponderosa*), Texas pine (*Pinus palustris*), spruce, California redwood (*Sequoia sempervirens*) and yellow fir (*Pseudotsuga douglasii*) have all been used for staves, but during recent years practically all pipes of this kind have been made either of redwood or fir, the other kinds of wood having proved to be less valuable for the purpose. At the present time fir is used much more extensively than redwood. It is less durable than redwood when placed in the ground under unfavorable conditions, but in other respects is considered to be just as good or better and costs materially less than redwood. The lumber for pipe should be of extra good quality. The following specifications for fir staves are typical requirements:

Staves shall be made of live timber, sound, straight grained, entirely free from all dead wood, rotten knots, dry rot, cracks, shakes, or any other imperfections or defects that might impair their strength or durability. Pitch pockets will be allowed, provided they do not extend more than one-fourth of an inch into the staves. Small, tight knots not over three-fourths of an inch in diameter, and not occurring oftener than one in 4 feet of stave will be allowed, as will sapwood on the inside of the stave so long as it does not extend more than half way through the stave at any point.

Staves may be from 10 to 30 feet in length, but not more than 10 per cent shall be less than 14 feet in length. Timber must be thoroughly seasoned, either by kiln or air drying, before being milled into staves.

Another requirement, not common, however, is that staves shall be milled from flat or bastard sawed lumber, those in which the edge grain passes through the stave in a distance less than one-half inch more than the thickness of the stave will be rejected.

Other general specifications are—

That the staves shall be dressed on both sides to true circles, and on the edges to conform to the radial lines of the pipe; that all staves shall be of uniform thickness, and each stave of uniform width throughout its entire

length; that the end of the stave shall be cut square, and shall be fitted with a saw kerf for the insertion of a metal tongue; in depth the saw kerf shall be one-sixteenth of an inch less than half the width of the tongue, and its position must be the same in all staves.

BANDS.

For bands, the usual specifications require soft steel of ultimate tensile strength equal to 55,000 to 65,000 pounds per square inch; elastic limit not less than one-half the ultimate tensile strength; elongation in 8 inches not less than 25 per cent, and the bands are required to stand bending, cold, 180° around a diameter equal to that of the specimen tested, without fracture on either side. Such steel is similar in quality to that used for steam boilers.

It is usual to specify that bands shall be provided with not less than 5 inches of cold-rolled thread or have upset ends; the idea being to insure as great strength in the threaded portion as in the body of the band. Each threaded end should be supplied with a standard hexagonal nut three-sixteenths of an inch thicker than the diameter of the band, and a plate washer of proper diameter and standard thickness.

In determining the size of bands many engineers have used a formula developed by the late A. L. Adams.[1] Four is the usual factor of safety. Bands less than three-eighths of an inch in diameter are not used. The following table prepared by Mr. Adams shows minimum sizes of pipe for which bands of several sizes are applicable.

Minimum sizes of pipe for which specified bands are applicable.

Size of band.	S equals $\frac{1}{4}$ ultimate tensile strength.	Band pressure per square inch.	E equals band pressure per linear inch.	Least external radius of pipe.	Band pressure per square inch.	E equals band pressure per linear inch.	Least external radius of pipe.
Inch.	*Pounds.*	*Pounds.*	*Pounds.*	*Inches.*	*Pounds.*	*Pounds.*	*Inches.*
$\frac{3}{8}$	1,650	650	122	13.5	750	140	11.8
$\frac{7}{16}$	2,250	650	142	15.8	750	164	13.7
$\frac{1}{2}$	2,950	650	163	18.1	750	187	15.7
$\frac{9}{16}$	3.725	650	183	20.4	750	211	17.65
$\frac{5}{8}$	4,600	650	203	22.6	750	234	19.6
$\frac{3}{4}$	6,600	650	244	27.0	750	281	23.5

The particular style of band to use, one piece or two piece, oval head or square head, depends upon the size of the pipe, etc. Standard patterns of each, as made by one of the leading manufacturers, with weights and dimensions, are given as follows.

[1] Trans. Amer. Soc. Civ. Engin., 41 (1899), p. 27.

Dimensions and weights of standard one-piece bands.

[Dimensions in inches and weights in pounds.]

Size of band.	Kind. Head.	Kind. Nut.	Threads. Diameter.	Threads. Length.	Threads. Per inch.	Nuts. Short diameter.	Nuts. Thickness.	Washers. Diameter.	Washers. Gauge No.	Washers. Hole.	Heads. Width.	Heads. Thickness.	Approximate length of rod required to form 1 head.	Weight per 100 plain round rods 15 feet long.	Weights. Nuts per 100.	Weights. Washers per 100.	Weights. Heads per 100.	Total weight per 100 bands 15 feet long.
3/8	Button..	Square....	7/16	4	14	7/8	1/2	1 1/4	14	1/2	3/4	5/16	3/4	578.3	8.0	2.4	2.4	591.1
	..do....	Hexagonal													7.0			590.1
	Square..	Square....									9/16	9/32	13/16		8.0		2.5	591.2
	..do....	Hexagonal													7.0			590.2
7/16	Button..	Square....	1/2	4 1/2	13	7/8	1/2	1 3/8	12	9/16	3/4	3/8	7/8	766.5	7.5	3.9	3.7	781.6
	..do....	Hexagonal													6.5			780.6
	Square..	Square....									21/32	5/16	7/8		7.5		3.8	781.7
	..do....	Hexagonal													6.5			780.7
1/2	Button..	Square....	9/16	5	12	1 1/16	5/8	1 1/2	12	5/8	15/16	13/32	15/16	1,000.5	14.0	4.4	5.2	1,024.1
	..do....	Hexagonal													13.0			1,023.1
	Square..	Square....									3/4	3/8	1 1/16		14.0		6.0	1,024.9
	..do....	Hexagonal													13.0			1,023.9
9/16	Button..	Square....	5/8	5	11	1 1/16	5/8	1 3/4	10	11/16	1	7/16	1	1,267.5	12.9	8.0	6.0	1,294.4
	..do....	Hexagonal													11.9			1,293.4
	Square..	Square....									27/32	13/32	1 5/32		12.9		8.2	1,296.6
	..do....	Hexagonal													11.9			1,295.6
5/8	Button..	Square....	11/16	5	11	1 1/4	3/4	1 3/4	10	3/4	1 1/16	7/16	1	1,564.5	24.3	7.7	8.7	1,605.2
	..do....	Hexagonal													20.2			1,601.1
	Square..	Square....									15/16	15/32	1 11/32		24.3		11.7	1,608.2
	..do....	Hexagonal													20.2			1,604.1
3/4	Button..	Square....	13/16	5	10	1 3/8	7/8	2	10	7/8	1 3/16	1/2	1 1/16	2,253.0	34.0	9.7	13.3	2,310.0
	..do....	Hexagonal													28.0			2,304.0
	Square..	Square....									1 1/8	9/16	1 5/8		34.0		20.2	2,316.9
	..do....	Hexagonal													28.0			2,310.9
13/16	Button..	Square....	7/8	5	9	1 7/16	7/8	2 1/4	9	15/16	1 3/8	9/16	1 1/8	2,644.5	38.5	13.5	16.5	2,713.0
	..do....	Hexagonal													30.5			2,705.0
	Square..	Square....									1 7/32	39/64	1 3/4		38.5		25.7	2,722.2
	..do....	Hexagonal													30.5			2,714.2
7/8	Button..	Square....	15/16	5	9	1 7/16	7/8	2 1/4	9	1	1 1/2	5/8	1 3/16	3,066.0	36.5	17.5	20.3	3,140.3
	..do....	Hexagonal													29.0			3,132.8
	Square..	Square....									1 5/16	21/32	1 7/8		36.5		32.2	3,152.2
	..do....	Hexagonal													29.0			3,144.7
1	Button..	Square....	1 1/16	5	8	1 5/8	1	2 1/2	9	1 1/8	1 9/16	11/16	1 1/4	4,005.0	53.2	17.5	27.7	4,103.4
	..do....	Hexagonal													44.5			4,094.7
	Square..	Square....									1 1/2	3/4	2 5/32		53.2		47.8	4,123.5
	..do....	Hexagonal													44.5			4,114.8
1 1/16	Button..	Square....	1 1/8	5	7	1 13/16	1 1/8	2 3/4	7	1 3/16	1 11/16	3/4	1 5/16	4,521.0	75.6	20.0	33.0	4,649.8
	..do....	Hexagonal													62.5			4,636.5
	Square..	Square....									1 19/32	51/64	2 5/16		75.6		57.6	4,674.2
	..do....	Hexagonal													62.5			4,661.1
1 1/8	Button..	Square....	1 3/16	5	7	2	1 1/4	2 3/4	7	1 1/4	1 3/4	13/16	1 7/16	5,068.5	101.0	19.3	40.5	5,229.3
	..do....	Hexagonal													87.0			5,215.3
	Square..	Square....									1 11/16	27/32	2 13/32		101.0		67.8	5,256.6
	..do....	Hexagonal													87.0			5,242.6

WOOD PIPE IN COURSE OF CONSTRUCTION.

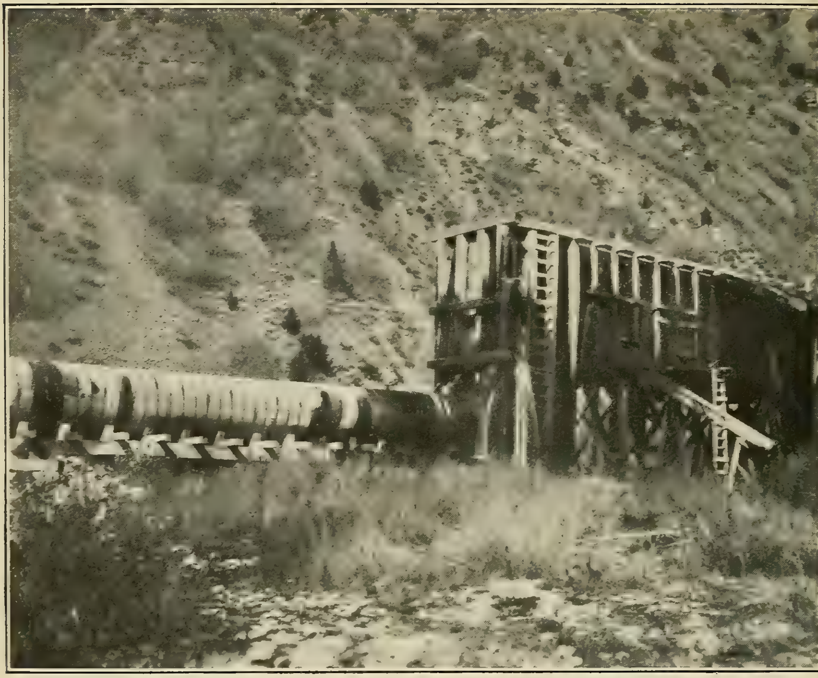

FIG. 1.—INTAKE OF PIPE-LINE AT LOGAN, UTAH.

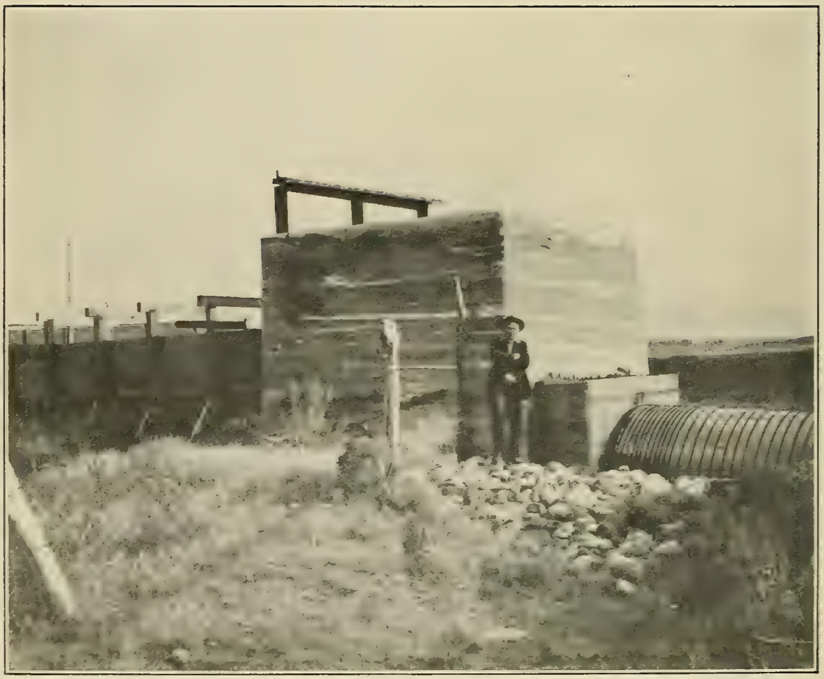

FIG. 2.—INTAKE OF PIPE-LINE CROSSING SNAKE RIVER NEAR BLISS, IDAHO.

Dimensions and weights of standard two-piece bands.

[Dimensions in inches and weights in pounds.]

Size of band.	Kind.	Threads.			Nuts.		Washers.			Heads.		Approximate length of rod required to form 1 head.	Weight per 100 plain round rods 15 feet long.	Weights.			Total weight per 100 bands 15 feet long.
		Diameter.	Length.	Per inch.	Short diameter.	Thickness.	Diameter.	Gauge No.	Hole.	Width.	Thickness.			Nuts per 200.	Washers per 200.	Heads per 200.	
$\frac{3}{8}$	Thread each end, square nut	$\frac{7}{16}$	4	14	$\frac{7}{8}$	$\frac{1}{2}$	$1\frac{1}{4}$	14	$\frac{1}{2}$	....	....	....	578.3	16.0	4.8	.....	599.1
	Thread each end, hexagonal nut													14.0		.....	597.1
	Button head each end									$\frac{3}{4}$	$\frac{5}{16}$	$\frac{3}{4}$		.....	......	4.7	583.0
	Square head each end	....	....	....	....	....	....	....	....	$\frac{9}{16}$	$\frac{9}{32}$	$\frac{13}{16}$		.....	......	5.0	583.3
$\frac{7}{16}$	Thread each end, square nut	$\frac{1}{2}$	$4\frac{1}{2}$	13	$\frac{7}{8}$	$\frac{1}{2}$	$1\frac{3}{8}$	12	$\frac{9}{16}$	....	....	....	766.5	15.0	7.7	.....	789.2
	Thread each end, hexagonal nut													13.0		.....	787.2
	Button head each end									$\frac{3}{4}$	$\frac{3}{8}$	$\frac{7}{8}$		.....	......	7.5	774.0
	Square head each end	....	....	....	....	....	....	....	....	$\frac{21}{32}$	$\frac{5}{16}$	$\frac{7}{8}$		.....	......	7.6	774.1
$\frac{1}{2}$	Thread each end, square nut	$\frac{9}{16}$	5	12	$1\frac{1}{16}$	$\frac{5}{8}$	$1\frac{1}{2}$	12	$\frac{5}{8}$	....	....	....	1,000.5	28.0	8.8	.....	1,037.3
	Thread each end, heaxagonal nut													26.0		.....	1,035.3
	Button head each end									$\frac{15}{16}$	$\frac{13}{32}$	$\frac{13}{16}$		.....	......	10.4	1,010.9
	Square head each end	....	....	....	....	....	....	....	....	$\frac{3}{4}$	$\frac{3}{8}$	$1\frac{1}{16}$		.....	......	12.0	1,012.5
$\frac{9}{16}$	Thread each end, square nut	$\frac{5}{8}$	5	11	$1\frac{1}{16}$	$\frac{5}{8}$	$1\frac{3}{4}$	10	$\frac{11}{16}$	....	....	....	1,257.5	25.8	15.9	.....	1,309.2
	Thread each end, hexagonal nut													23.8		.....	1,307.2
	Button head each end									1	$\frac{7}{16}$	1		.....	......	12.1	1,279.6
	Square head each end	....	....	....	....	....	....	....	....	$\frac{27}{32}$	$\frac{13}{32}$	$1\frac{5}{32}$		.....	......	16.4	1,283.9
$\frac{5}{8}$	Thread each end, square nut	$\frac{11}{16}$	5	11	$1\frac{1}{4}$	$\frac{3}{4}$	$1\frac{3}{4}$	10	$\frac{3}{4}$	....	....	....	1,564.5	48.5	15.4	.....	1,628.5
	Thread each end, hexagonal nut													40.4		.....	1,620.3
	Button head each end									$1\frac{1}{16}$	$\frac{7}{16}$	1		.....	......	17.4	1,581.9
	Square head each end	....	....	....	....	....	....	....	....	$\frac{15}{16}$	$\frac{15}{32}$	$1\frac{11}{32}$		.....	......	23.4	1,587.9
$\frac{3}{4}$	Thread each end, square nut	$\frac{13}{16}$	5	10	$1\frac{3}{8}$	$\frac{7}{8}$	2	10	$\frac{7}{8}$	....	....	....	2,253.0	68.0	19.4	.....	2,340.4
	Thread each end, hexagonal nut													56.0		.....	2,328.4
	Button head each end									$1\frac{3}{16}$	$\frac{1}{2}$	$1\frac{1}{16}$		.....	......	26.6	2,279.6
	Square head each end	....	....	....	....	....	....	....	....	$1\frac{1}{8}$	$\frac{9}{16}$	$1\frac{5}{8}$		.....	......	40.3	2,293.3
$\frac{13}{16}$	Thread each end, square nut	$\frac{7}{8}$	5	9	$1\frac{7}{16}$	$\frac{7}{8}$	$2\frac{1}{4}$	9	$\frac{15}{16}$	....	....	....	2,644.5	77.0	26.9	.....	2,748.4
	Thread each end, hexagonal nut													61.0		.....	2,732.4
	Button head each end									$1\frac{3}{8}$	$\frac{9}{16}$	$1\frac{1}{8}$		.....	......	33.0	2,677.5
	Square head each end	....	....	....	....	....	....	....	....	$1\frac{7}{32}$	$\frac{39}{64}$	$1\frac{3}{4}$		.....	......	51.4	2,695.9
$\frac{7}{8}$	Thread each end, square nut	$\frac{15}{16}$	5	9	$1\frac{7}{16}$	$\frac{7}{8}$	$2\frac{1}{4}$	91		....	....	....	3,066.0	73.0	35.0	.....	3,174.0
	Thread each end, hexagonal nut													58.0		.....	3,159.0
	Button head each end									$1\frac{1}{2}$	$\frac{5}{8}$	$1\frac{3}{16}$		.....	......	40.5	3,106.5
	Square head each end	....	....	....	....	....	....	....	....	$1\frac{5}{16}$	$\frac{21}{32}$	$1\frac{7}{8}$		.....	......	64.4	3,130.4

Dimensions and weights of standard two-piece bands—Continued.

[Dimensions in inches and weights in pounds.]

Size of band.	Kind.	Threads.			Nuts.		Washers.			Heads.		Approximate length of rod required to form 1 head.	Weight per 100 plain round rods 15 feet long.	Weights.			Total weight per 100 bands 15 feet long.
		Diameter.	Length.	Per inch.	Short diameter.	Thickness.	Diameter.	Gauge No.	Hole.	Width.	Thickness.			Nuts per 200.	Washers per 200.	Heads per 200.	
	Thread each end, square nut	$1\frac{1}{16}$	5	8	$1\frac{5}{8}$	1	$2\frac{1}{2}$	9	$1\frac{1}{8}$	....	....	....	4,005.0	106.3	35.0	.....	4,146.3
	Thread each end, hexagonal nut													89.0		.....	4,129.0
	Button head each end	....	....	....	....	....	....	....	....	$1\frac{9}{16}$	$\frac{11}{16}$	$1\frac{1}{4}$		.....	.....	55.4	4,060.4
	Square head each end									$1\frac{1}{2}$	$\frac{3}{4}$	$2\frac{5}{32}$		.....	.....	95.6	4,100.6
$1\frac{1}{16}$	Thread each end, square nut	$1\frac{1}{8}$	5	7	$1\frac{13}{16}$	$1\frac{1}{8}$	$2\frac{3}{4}$	7	$1\frac{3}{16}$	....	....	....	4,521.0	151.1	40.0	.....	4,712.1
	Thread each end, hexagonal nut													124.9		.....	4,685.9
	Button head each end	....	....	....	....	....	....	....	....	$1\frac{11}{16}$	$\frac{3}{4}$	$1\frac{5}{16}$		.....	.....	66.0	4,587.0
	Square head each end									$1\frac{19}{32}$	$\frac{51}{64}$	$2\frac{5}{16}$		.....	.....	115.2	4,636.2
$1\frac{1}{8}$	Thread each end, square nut	$1\frac{3}{16}$	5	7	2	$1\frac{1}{4}$	$2\frac{3}{4}$	7	$1\frac{1}{4}$	....	....	....	5,068.5	202.1	38.6	.....	5,309.1
	Thread each end, hexagonal nut													174.0		.....	5,281.1
	Button head each end	....	....	....	....	....	....	....	....	$1\frac{3}{4}$	$\frac{13}{16}$	$1\frac{7}{16}$		.....	.....	81.0	5,149.5
	Square head each									$1\frac{11}{16}$	$\frac{27}{32}$	$2\frac{13}{32}$		.....	.....	135.5	5,204.0

For determining the spacing of bands many formulas have been developed and diagrams have also been prepared for graphical determination.[1] The following formula prepared by S. Fortier has been very commonly used:

$d=\frac{S}{CPR}$ in which d equals distance between bands in inches.

S=maximum tensile strength of each band in pounds.

P=pressure of water in pounds per square inch in bottom of pipe.

R=internal radius of pipe in inches.

C=coefficient to allow for strain caused by swelling of wood, and includes safety factor of about 4 or 5 for bands.

The spacing of bands on some of the earlier pipes built was as wide as 16 inches or more, but at present 10 inches is considered the maximum permissible, and on some important recent work the maximum was placed much lower than this, even though the pressures did not require it.

There is a tendency for the ends of staves to spring out when subjected to high pressure and often under light heads where bands are farther apart, if the pipe is exposed to the sun. In order to over-

[1] Engin. News, 60 (1908), p. 343.

come this tendency it is now a common practice to specify additional bands at the joints, and to bring all joints within a space of 2 to 4 feet.

COUPLING SHOES.

The designing of shoes is now left principally to the manufacturers, and selection may be made from a number of patterns. Light weight in most instances, where not subject to excessive corrosion, is the chief consideration after strength equal to that of the bands is assured. Cast-iron shoes were used principally during the earlier years of continuous stave pipe building. They were heavy and easily broken, and on this account common cast iron has given place to malleable cast iron and steel. Malleable iron for this purpose should be of the most tenacious character, capable of standing considerable hammering without fracture. The tensile strength should be not less than 40,000 pounds per square inch of section. Steel for shoes should in quality be equal in all respects to that required for bands.

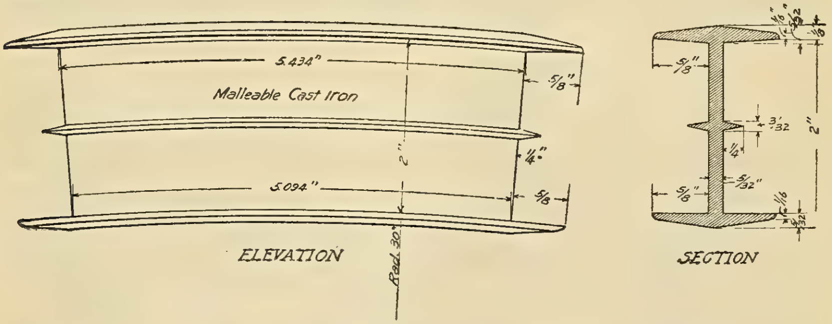

FIG. 1.—Kelsey joint.

JOINTS.

In designing butt joints, the use of thin steel clips inserted in saw kerfs is almost universal. Some variations from this form of joint have been tried, however. In the "Dwelle" pipe staves were tongued and grooved at the ends. In the "Wheeler" pipe a loose oak tongue was used instead of a steel clip, and on a pipe at Victor, Colo., clips of papier-mâché were used. None of these proved satisfactory. Another joint, known as the "Kelsey butt joint," is notably different from the usual type. This was used on pipe lines of Provo City, the Spanish Fork waterworks, and others in Utah, designed by F. C. Kelsey a number of years ago, and on the Blacksmith Fork pipe line built in the northern part of the State in 1912. This joint (fig. 1) consists of a malleable casting which takes the place of the metal clips and also fits tightly over the ends of the abutting staves. It is very highly recommended by engineers who have tried it, and appears to possess considerable merit. The cost is somewhat

more than that of the thin metal clips, but it is claimed that the difference in cost is more than offset by the time saved in building the pipe and by eliminating expense of saw kerfs.

For the ordinary clips No. 12 gauge steel or wrought iron is used. As a rule they are 1½ inches wide and the length is one-eighth inch greater than that of the saw kerf, so as to allow the ends to project one-sixteenth inch at each edge of the stave.

PROTECTIVE COATING OF BANDS.

The bands of continuous stave pipe are nearly always dipped or painted with some form of protective coating, and sometimes the shoes also. For this purpose there are numerous patented or trade preparations on the market, some one of which may be specified. They consist usually of asphaltum in combination with linseed oil or other ingredients for tempering and reducing, and, as a rule, are to be applied hot. Some manufacturers, however, are coming to recommend a cold dip instead of the hot, believing it to be equally effective.

INTAKES AND OUTLETS OF PIPE LINES.

The design of the intake and outlet of every pipe line must be a matter depending upon local conditions and character of service for which the pipe is intended. For this reason standard designs can not have a wide range of adaptability, but some points that usually require consideration in designing such structures for service of whatever nature are common enough to merit brief discussion.

The material used for intakes and outlets is usually either wood, concrete, or masonry. Wood has been used extensively and in first cost is usually cheaper than other materials. Its life is comparatively short, and if economic conditions will permit, something more durable should be employed. In connection with power developments, wells of cribwork have often been used to give the desired entrance head, and the same kind of construction is sometimes employed at outlets also. Examples of wood and concrete intakes are shown in Plate II. Figure 1 shows the intake to the pipe of the Logan (Utah) City Power Co. and figure 2 the intake of the pipe line of the Kings Hill irrigation project crossing the Snake River near Bliss, Idaho.

The plans of a wooden intake and an outlet box, fairly typical of this class of irrigation structures, are shown in a previous bulletin.[1] These were built in 1894, and after nine years of satisfactory service were still in use, though to some extent decayed. Lumber at the time these were built cost $15 per thousand delivered along the canal.

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[1] U. S. Dept. Agr., Office Expt. Stas. Bul. 131, p. 49.

Due to general advance in the price of lumber in late years and the reduction in the cost of cement, concrete has come to be the material principally used for structures of this kind.

For municipal water supplies, intakes may require elaborate controlling works, including settling chambers, sand gates, etc., and in some localities steam pipes for heating the receiving chamber are provided as a precaution against freezing.[1] But ordinarily for irrigation or power lines such structures need not be elaborate or expensive. An example of this type of construction is shown in figure 2, the intake of a 72-inch inverted siphon on the Kings Hill irrigation project, Idaho. Another example in which the water enters the pipe

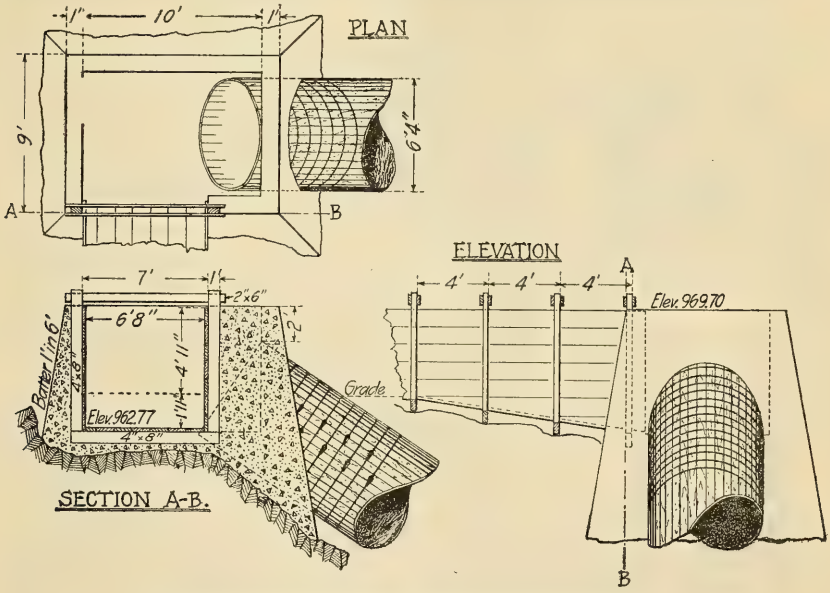

FIG. 2.—Intake of 72-inch pipe on King Hill project.

from an earth ditch instead of from a flume is illustrated by figure 3, intake of Poisin Basin siphon, Kings Hill project, Idaho. In the foregoing examples the concrete was poured around the pipe so as to form a tight connection, and the portions so incased were given additional bands. In some instances a section of cast iron or steel pipe is set in the concrete and a junction is made between that and the wood pipe. In other instances where the concrete and wood are joined, space for calking is provided by making the opening through the concrete slightly larger than the external diameter of the pipe. Either of the alternatives from the first plan given makes it possible to replace or repair the end of the wood pipe with greater facility, though the calked joint may be more difficult to keep water-tight.

[1] Engin. Rec., 66 (1912), p. 425. Intake of Denver Union waterworks.

On most irrigation systems the head of water carried fluctuates more or less and, as a rule, is far below normal for a considerable period in the spring and again for a time in the fall. At such times siphons and pipe lines may not run full. This condition may be unfavorable to their life and, as a precaution against it, gates have in a few instances been placed at the outlets as a means of throttling the discharge so as to keep the pipe full at all times. Such provision was made at the outlet of the 84-inch pipe line of the Pueblo Rocky Ford Irrigation Co., and the same practice might be followed to advantage in many other places.

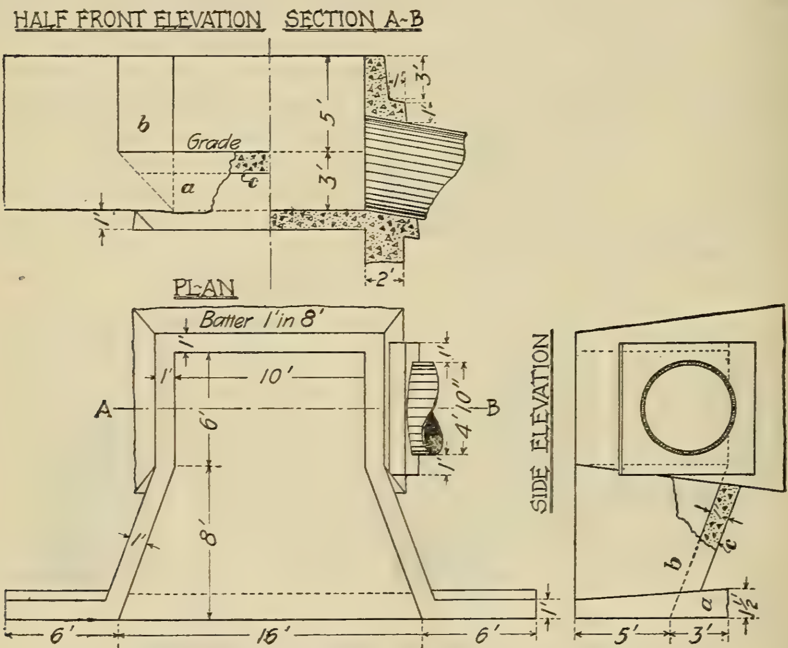

FIG. 3.—Intake of "Poison Basin" siphon, King Hill project, Idaho.

To prevent weeds or coarse débris of any kind from entering pipe lines, gratings are usually provided at intakes. However, unless carefully watched, the accumulation of weeds at the grating is liable to obstruct the entrance so as to cause the water to overflow canal banks. The danger of this, and of the serious damage which might result in many instances, have led to the removal of gratings which could not be inspected frequently. For irrigation service, where water is not carried during the winter, iron gratings are very satisfactory, but in places where ice is troublesome wooden gratings are considered better, particularly if they project above the water, for the reason that ice does not form on the wood so readily.

SPILLWAYS.

As a precaution against damage that might result from accidental stoppage of the pipe and to facilitate quick emptying in case of accident, spillways should be provided near the intake to siphons on irrigation systems where it is feasible to do so.

AIR VALVES.

At every summit of a wood-pipe line, an air valve or chimney should be placed. This is to allow air to enter so as to prevent a vacuum and liability of collapse when the pipe is emptied, as well as to permit the escape of air that may accumulate at such points. Of the various types of air valves on the market one in common use is illustrated by figure 4. A valve of this kind remains open until closed by internal water pressure, and by means of an angle valve air that accumulates while the pipe is in service may be released by hand.[1] Where practicable, iron pipes open at the top are carried to a point above the hydraulic gradient in preference to the use of air valves at summits. Air valves and chimneys are usually connected to wood pipe by means of cast saddles, which are held in place by steel bands (Pl. III, fig. 1).

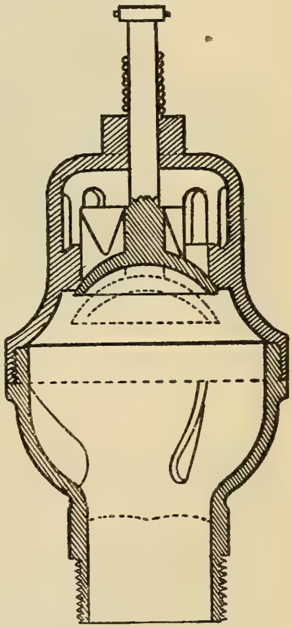

FIG. 4.—A type of air valve. (Patented.)

BLOW-OFFS.

Blow-offs are attached near the bottom at low points of the wood pipes in a manner similar to that of attaching chimneys, and a sufficient number should be provided so that every section of the pipe line may be drained and flushed out. Ordinary gate valves are usually employed for this purpose, the size to use being dependent on conditions. In lines where a large amount of silt is liable to accumulate, such valves should be of large size.

On the 84-inch pipe of the Pueblo, Rocky Ford Irrigation Co. the 6-inch blow-offs operating under a head of 75 feet would completely clog up with grass, leaves, and débris. To clean the pipe it was necessary to cut a number of holes through it. These were made 30 inches square. New blow-off gates of this size were designed to replace the 6-inch ones originally used.

[1] For other designs of air valves see Jour. New England Water Works Assoc., 8 (1893–94), p. 27; Engin. News, 33 (1895), p. 234; Trans. Amer. Soc. Civ. Engin., 36 (1896), p. 23.

The experience with 6-inch blow-offs on the Kings Hill pipes was similar. Silt in the nipples became so compact that water could not be forced through, and small holes were bored through the pipe to drain it. Then the valves were removed and cleaned. Flushing the valves occasionally would perhaps obviate this trouble. Where the water carries extraordinary quantities of sand or silt it may be advisable to provide sand boxes near the intakes. This was done on the Santa Ana Canal in California,[1] the lower Yakima Irrigation Co.'s canal in Washington, and on other canals.

On the 31-inch siphon at Prosser, Wash., a 12-inch valve was used. (Sunnyside Canal, U. S. Reclamation Service.)

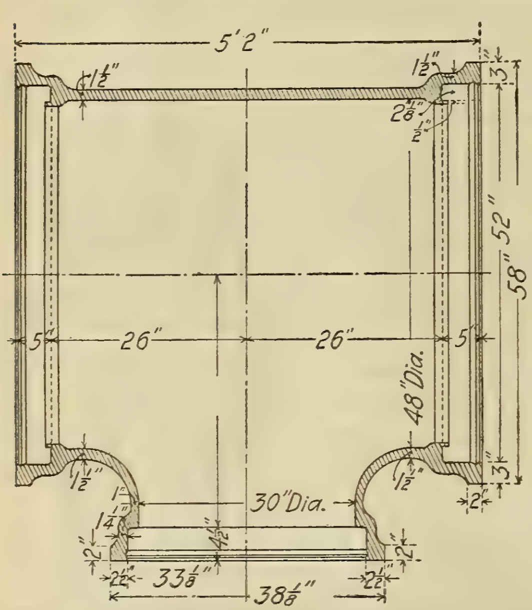

FIG. 5.—Forty-eight-inch special tee for joining wood pipe to cast-iron pipe.

Where pipes are kept full during the winter, air valves and blow-off gates should be protected against freezing.

CONNECTIONS WITH OTHER KINDS OF PIPE.

On the Sunnyside Canal in Washington the portions of the Mabton and Prosser siphons at intake and outlet ends where the pressures are light are made of concrete pipe. These are joined to continuous stave wood pipes which sustain the greater pressures. In other pipe lines wood is used for heads up to approximately 200 feet, and steel or cast iron for greater pressures. Again, where curves too sharp for the wood pipe are required, in passing under railroads and in other situations, it is frequently found necessary to join continuous stave pipe to that of some other type.

A common practice in joining wood and cast iron or steel is illustrated by Plate III, figure 2. The wood pipe is made to overlap the metal pipe, and by means of the bands is cinched up to make a tight joint. The usual lap is 12 to 18 inches, but laps of as much as 4 feet have been made.

A connection of this kind is criticized on the ground that it does not permit proper saturation of the wood pipe where it overlaps the

[1] Trans. Amer. Soc. Civ. Engin., 33 (1895), p. 129.

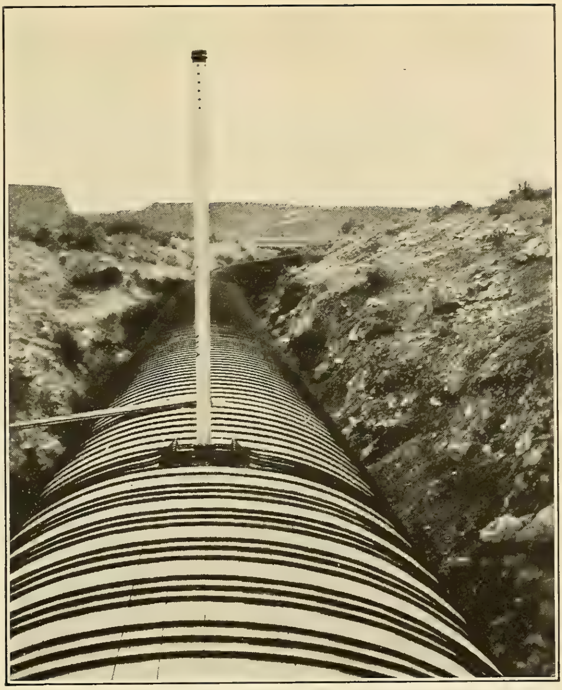

FIG. 1.—CHIMNEY ATTACHED TO WOOD PIPE.

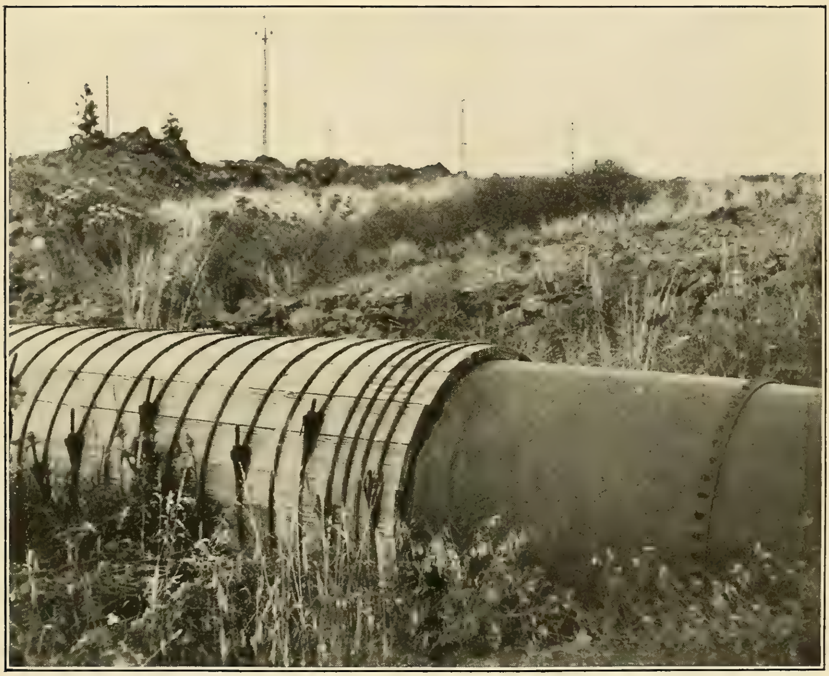

FIG. 2.—UNION OF WOOD AND STEEL PIPE.

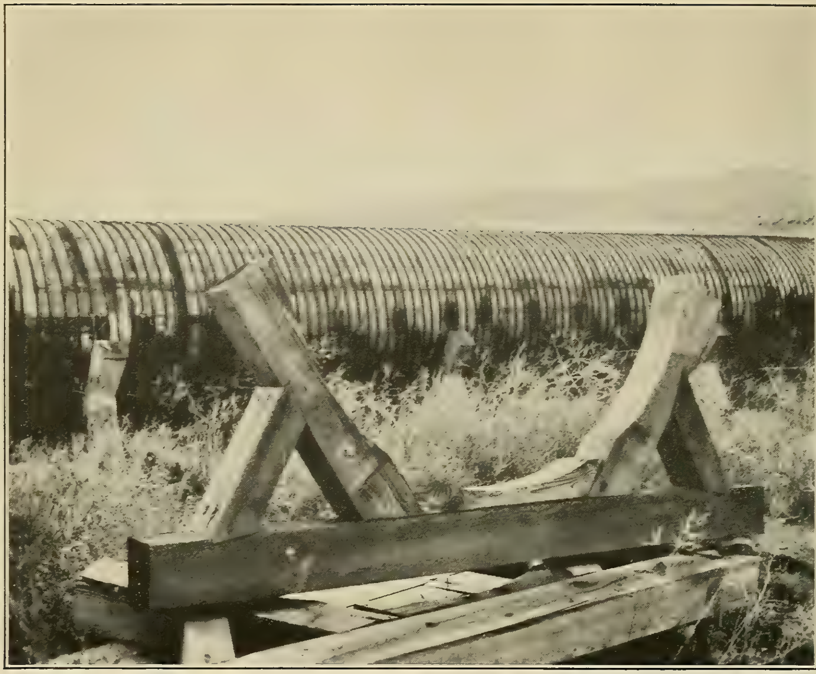

FIG. 1.—CRADLES USED TO SUPPORT WOOD PIPE, KING HILL PROJECT, IDAHO.

FIG. 2.—STEEL ANGLE IN 44-INCH PIPE, SHOWING METHOD OF JOINING WOOD AND STEEL AND METHOD OF ANCHORING PIPE ON STEEP SLOPE.

metal, thus leaving it subject to decay. It is considered better practice to insert the wood pipe into the metal pipe and calk with lead and oakum. To do this usually requires a special coupling either of cast iron or steel. An example of a cast fitting illustrating this method of joining wood pipe and cast-iron pipe is shown by figure 5, and another of steel for uniting wood pipe and steel pipe by figure 6. An important feature in both of these designs is the thimble or flange which fits inside the wood staves to prevent them from being forced in by the calking.

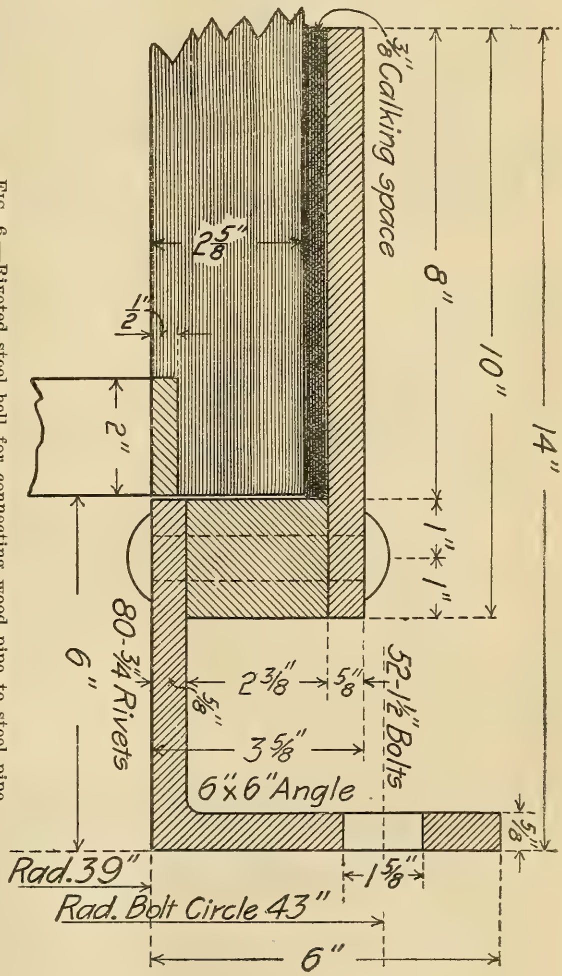

Fig. 6.—Riveted steel bell for connecting wood pipe to steel pipe.

CRADLES.

If continuous stave pipes are built above ground it is usually best to support them in "cradles" or "chairs." In the design and spacing of supports of this kind the ideas and judgment of engineers differ and as yet there is no standard practice.

Cradles of the general type shown by figure 7, A, were used on several large pipe lines of the Kings Hill irrigation system in Idaho, and they appear to be well designed. On some pipe lines the 2 by 12 inch mudsills are continuous; on others, blocks 18 inches long are used. The use of short blocks in this way is more economical of material, and requires less grading. The cradles of the type shown by Plate IV, figure 1, were spaced 6 feet center to center under a 54-inch pipe, and to support a pipe 100 inches in diameter cradles of the same type of 8 by 8 inch material

were used with 6-foot spacing. Supports similar to the other cradle shown (fig. 7, B) have been used on a number of pipe lines. The Logan (Utah) city power pipe line rests on such cradles spaced 4 feet center to center, with no mudsill blocks beneath the 6 by 6 inch

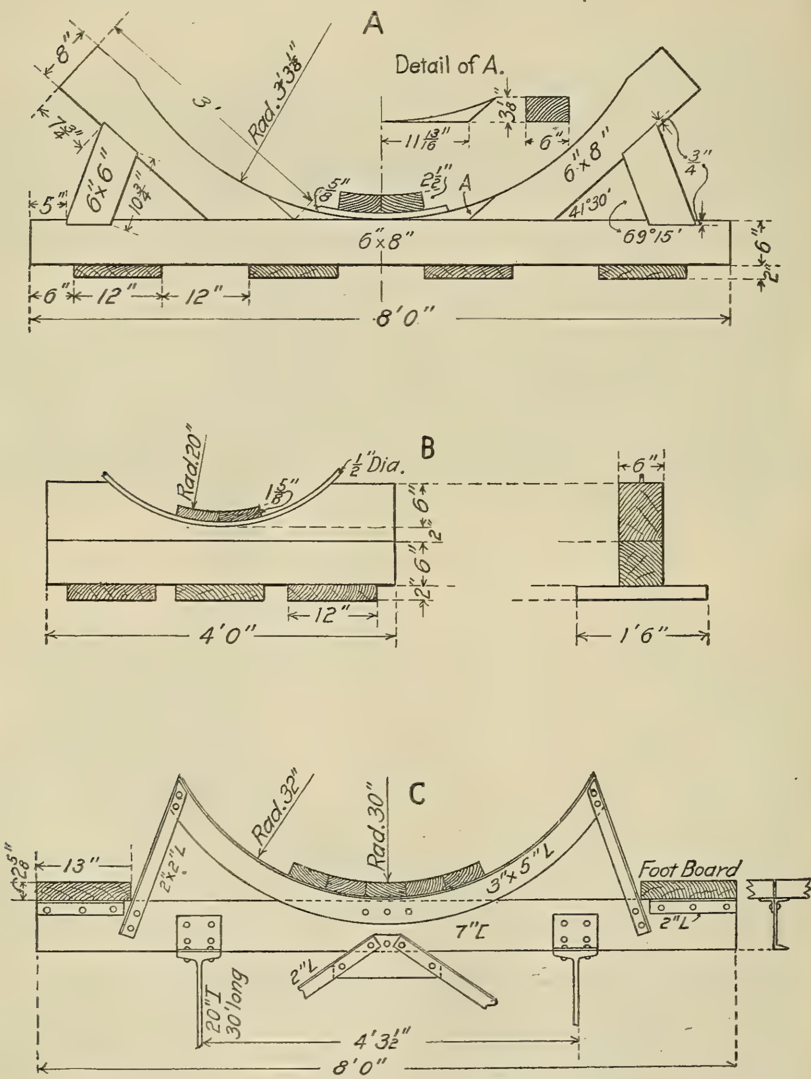

FIG. 7.—Cradles for carrying stave pipe.

timber. The 48-inch pipe of the Portland Flouring Mills Co., at Dayton, Wash., is carried on cradles 12 feet apart, and while this spacing is unusually wide the support appears to be ample.

Some large wood-pipe lines carried across rivers and ravines on bridges, or trestles of steel, are supported by cradles also of steel.

The Snake River crossing of the Kings Hill project, near Bliss, Idaho, and the new trestles of the Denver Union Water Co., afford good examples of such cradles (fig. 7, C).

The 84-inch pipe of the Pueblo, Rocky Ford Irrigation Co. is in places supported on rock cradles set about 15 feet apart.

ANCHORING PIPES.

In order to secure surface pipes against water thrust at sharp horizontal curves, and to guard against the tendency to creep on steep inclines, anchorage in some manner is sometimes necessary. One method of anchoring a 44-inch pipe, as well as the way of designing an angle too sharp for the curvature of wood pipe, is illustrated by Plate IV, figure 2. Another method is to build around the pipe a pier or mass of concrete or masonry to serve as anchorage.

LOCATION OF CONTINUOUS STAVE PIPE LINES.

The location of a pressure pipe line is very often a simple matter, particularly where the distance traversed is short, but in the case of long lines of wood pipe a proper and satisfactory location may involve a number of important considerations. This is particularly true if the line is to traverse a rough, mountainous region. Many such pipe lines have been built without due knowledge or appreciation of the importance of certain factors, and failures or unsatisfactory service may frequently result from faulty location.

As a rule, a pipe line must follow more or less closely the variations of the ground surface, but in both plan and profile sharp curves should be avoided as much as possible. The introduction of sharp curves tends to increase the cost and difficulty of construction as well as of maintenance and repairs and to decrease the carrying capacity. Horizontal and vertical curves should not be placed in the same section of pipe, and a tangent between curves is always desirable. The degree of curvature permissible depends largely on the diameter of the pipe and upon the thickness and kind of staves. A radius of 60 times the diameter of the pipe is usually taken as a measure of allowable curvature, though sharper curves are not uncommon.

A wooden pipe should be located so as to be under all conditions entirely below the hydraulic gradient, and in making extensions, or in taking off branches at any time from a line already established, care should be taken not to lower the hydraulic gradient so as to leave the original pipe above it. Carelessness with reference to these considerations has in some instances been the cause of serious damage and expense.

On the point as to what the minimum distance below the hydraulic gradient should be, engineers differ in opinion. Assuming that pressure sufficient to keep the staves well saturated is necessary to pre-

vent decay, some engineers advocate 50 feet as the minimum so far as it is possible to secure such location, while others place it at 25 feet. With reference to the relation of pressure to durability of the wood, much may depend on other conditions of the location, particularly as to whether or not the pipe is placed in contact with the soil. If the pipe is placed in the ground or in contact with the soil, a pressure head of 50 feet or more is preferable to anything less, but if it is kept free from contact with the soil, 15 feet below the hydraulic gradient is as good as 50. By locating the pipe close to the hydraulic gradient fewer bands are required, but nothing is saved in keeping the pressure lower than 20 feet of head.

Evidence based on the experience of the past 20 years appears to be sufficient to show that, in general, continuous stave pipe lines should be located above ground and free from all contact with it, though opinions diametrically opposite with reference to this point have prevailed and still prevail. By those who favor locating pipes in the ground, it is argued that they are thus better protected from injury from fire, freezing, falling rocks, falling trees, landslides, etc., and that the life of the wood will be prolonged. In answer to which it may be claimed that a pipe line properly patrolled and maintained is seldom in serious danger from fire; the velocities as a rule are a sufficient safeguard against freezing in most places where such pipes are used, though wood pipes, even if frozen, may be easily repaired; in a region so rough that danger from landslides or falling rocks is a matter for consideration, the cost of excavating a trench is usually very great and material suitable for backfilling difficult or impossible to obtain, so that other means of protecting the pipe from such injury may be much more economical; and while under ideal conditions as to character of soil, depth of covering, pressure, etc., the life of a pipe in the ground might be longer than that of one fully exposed, experience shows conclusively that in practice there is great uncertainty as to conditions; that they are seldom ideal in all respects, and that burying has shortened the life of many pipes, both by decay of wood and by corrosion of bands. The conditions of a pipe above ground may be easily determined at any time, and if repairs are required they can be made with much less difficulty and expense than would otherwise be possible. If, however, reasons appear sufficient to justify placing a pipe in the ground, as they may in some instances, it is best to insure a deep covering of a nature that will most nearly exclude air from the pipe, particularly if the water pressure is light. Gravel, shell rock, or other porous material is not satisfactory for backfilling.

Summits and depressions in the line should be avoided as far as consistent with economical location. Where water courses are to be

crossed it is usually best to carry the pipe line over the stream rather than under it. This facilitates draining the pipe, and repairs can be more easily made.

CONSTRUCTION OF CONTINUOUS STAVE PIPE.

Where the pipe is to be built in a trench, the excavation is made from 1 to 2 feet wider than the diameter of the pipe. Then the staves of the lower half of the pipe are set up in a U-shaped form made usually of 1½-inch gas pipe bent on a curve equal to the outside diameter of the pipe. Another piece of gas pipe bent into a circle, of diameter slightly less than that of the wood pipe, with the ends overlapped and spread so that it will stand alone, is set on the lower staves already placed, and serves as a form for the upper part. If wooden cradles are used and two-piece bands, the lower section of the band, set in a cradle, is sometimes used as the bottom form instead of the gas pipe. A few bands sufficient to hold the staves in place are then slipped on, and the final banding is completed by other men, the spacing of each section being marked along the pipe according to tables or profiles in the hands of the foreman. During the progress of lining up and partially tightening the bands, the pipe is rounded out evenly and the staves are driven up to make the butt joints tight. Wooden mallets are used for the "coopering," and in driving home the staves iron-bound hardwood blocks are used with sledge hammers.

The end driving must usually be done repeatedly as the bands are tightened, care being exercised not to bruise or injure the staves. The final cinching may be delayed somewhat and should be done with careful judgment, particularly where the spacing is close, in order to avoid crushing the wood or shearing quarter-sawed staves. Special braces or wrenches with long shanks and short leverage are generally used for this work, each builder, as a rule, designing his own tools. Curves are made by crowding or pulling the partially banded pipe to the desired position with jackscrews or blocks and tackle.

A pipe-laying gang usually consists of from 8 to 16 men, the number depending on the closeness of banding, etc. The speed of construction depends upon the size of the pipe, spacing of bands, curvature, etc. On a 48-inch pipe built at Clarkston, Wash., in 1906, 250 feet was the most that was laid in 10 hours, and the amount ran down to as low as 50 feet where work was difficult.

According to J. D. Schuyler,[1] 150 to 300 feet of 34-inch pipe was made per day by a crew at Denver, Colo., the number of bands placed ranging from 700 to 1,000, while on 44-inch pipe 500 bands were placed per day. In 1910 a 48-inch pipe, 10 miles long under a

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[1] Trans. Amer. Soc. Civ. Engin., 31 (1894), p. 135.

maximum head of 130 feet, was built for the Denver Union Water Co. The contracting firm states that this was done in 75 days, with a force consisting of 150 men and 100 teams, and that this included hauling 30,000 tons of material an average of 10 miles on wagons. This is considered to be very rapid construction for a pipe of this size laid in a trench averaging 7 feet deep.

In building a long line of continuous stave pipe it is customary to employ several crews at convenient intervals of a thousand feet or more. The different sections of pipe so built are joined by cutting staves to fit, allowing about one-eighth-inch extra length so that when sprung in place the end joints come tight.

COST OF CONTINUOUS STAVE PIPE.

The cost of continuous stave pipe of any particular size varies so much according to design, spacing of bands, location relative to transportation lines, conditions affecting erection, etc., that it is impossible to give general costs, but some data of a specific nature relative to certain pipe lines which have been built may be of value for purposes of comparison.

Eighteen-inch.—At Astoria, Oreg., 7½ miles of 18-inch pipe built in 1895.[1] Staves, fir, 1⅝ inches thick, milled from 2 by 6 inch lumber. Bands, seven-sixteenths inch diameter upset to one-half inch at threads. Clips No. 12, B. W. G., 1½ inches wide, treated. Shoes, Allen patent, malleable iron, weight 10 ounces each. Contract prices of steel in bands, 4.8 cents per pound. Lumber, gross measurement, $35.40 per 1,000 feet b. m. Average spacing of bands, 5$\frac{9}{16}$ inches. Cost of pipe to the city, 90.33 cents per linear foot, including accessories or 76 cents excluding them. These figures are not the actual cost of building the pipe, as Mr. Adams says: "It is presumable that the contract prices represent a profit of from 12½ to 15 per cent." The approximate cost of replacing this line with one of the same size and length in 1911 was $75,000, redwood staves 1½ inches thick being used in the new pipe. The cost given includes engineering expense.

Thirty inch.—At Denver, Colo., in 1889,[2] a 30-inch pipe 16.4 miles long required 1,869,000 feet b. m. of Texas pine, which cost $51,399.28, at $27.50 per M, and 271,900 half-inch bands, which cost $54,299.55; erection of pipe by contract, at 5.1 cents per band, $13,866.03; total, $119,564.86, or $1.36½ per linear foot. Trenching cost 48.3 cents per foot in addition to foregoing.

At Jerome, Idaho, 1912, 1,529 feet; 30 inches diameter; fir staves, 1⅝ inches thick; bands, one-half inch diameter; pressure, 0 to 47 feet; average haul, 10 miles; built in trench and buried 2 feet deep. Cost, including everything except engineering and administration, $2,922, or $1.91 per linear foot.

At Idaho Falls, Idaho, 1905; 800 feet; 30 inches diameter; fir, one-half inch bands; maximum head, 34 feet; supported on wood cradles. Cost, $1.55 per linear foot, including everything.

At Kennewick, Wash., 1908; 9,490 feet; 30 inches diameter; head, 0 to 180 feet; built by contract on prepared foundation for $1.85 per foot. Includes delivery of material at railroad point, but no haul or earthwork.

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[1] Trans. Amer. Soc. Civ. Engin., 36 (1896), p. 1.

[2] Trans. Amer. Soc. Civ. Engin., 31 (1894), p. 143.

Thirty-two inch.—At North Yakima, Wash., 1894; Redwood siphon 940 feet long; 32 inches diameter; maximum head, 90 feet; bands, one-half inch diameter; built by force account for $2,500, equals $2.66 per linear foot. Duplicated by contract, 1903, for same figure.

At Filer, Idaho, 1901; 1,300 feet; 32 inches diameter; fir staves, 1⅝ inches thick, at $40 per thousand feet b. m. on basis of 2 by 6 inch lumber; bands, one-half inch diameter, 57 cents each; malleable iron shoes, 4 cents each; tongues, ⅛ by 1½ by 5$\frac{7}{16}$ inches, 3 cents; pressure head, 0 to 40 feet; work done by force account; wages, $2.50 for 10 hours, and foreman $5; hauling material 8 miles, $75; erecting on top of ground, approximately $250. Cost of staves and steel laid down at Filer, $1.35 per foot of pipe; haul and erecting, 25 cents; total approximately, $1.60 per foot.

Thirty-six inch.—At Jerome, Idaho, 1912; 650 feet; 36 inches diameter; head, 0 to 43 feet; staves, fir, 1⅝ inches thick; band, one-half inch diameter; built in trench and buried 2 feet deep; average haul, 4 to 5 miles. Cost, including everything except engineering and administration, $1,596, or $2.46 per foot.

Forty inch.—At Jerome, Idaho, 1912; 3,113 feet; 40 inches diameter; head, 0 to 100 feet; fir staves, 1⅝ inches thick; bands, one-half inch diameter; built in trench and buried 2 feet deep; average haul, 10 miles; cost, $8,933, or $2.87 per foot, including everything except engineering and administration.

Forty-two inch.—At Jerome, Idaho, 1912; 980 feet; 42 inches diameter; head, 0 to 51 feet; staves, fir, 1⅝ inches thick; bands, one-half inch diameter; built in trench and buried 2 feet deep; average haul, 4 to 5 miles; cost, $2,556, or $2.61 per foot, including everything except engineering and administration.

Forty-four inch.—At Wenatchee, Wash., 1902–3; 9,000 feet; 44 inches diameter; maximum head, 235 feet; bands, one-half inch diameter; fir staves, 1⅝ inches thick; laid in trench, and on bridge across Wenatchee River; contract price for pipe, $2.20 per linear foot. Excavating and backfilling not included.

At Palisades, Colo., 1909–10; 3 fir pipes, 44 inches diameter; 2,850 feet; 1,055 and 1,150 feet in length; cost by contract, $3.15, $3.25, and $2.90 per linear foot, respectively. No earthwork included.

Forty-eight inch.—At Palisades (orchard mesa), Colo., 1909–10; for 6 pipes 48 inches in diameter and varying lengths and heads, the unit prices ranged from $2.40 per foot up to $4.75 per foot, the average of the six being $3.52; material, fir.

At Deer Park, Wash. (about 1909), 94,000 feet of fir pipe; head, 0 to 70 feet, built in trench; contract price, $2.35 per foot, includes delivery of all material at railroad point and erection of pipe, but no haul or earthwork.

Forty-eight inch.—At Clarkston, Wash., 1906; fir staves, 1⅝ inches thick, ½-inch bands; built in trench by force account, for light head; cost, $2.25 per foot, no earthwork included. Foreman received $3.50 per day and other men $2.50 for 10 hours.

Fifty-eight inch.—At Pueblo, Colo., 1907; 2,277.5 feet; cost by contract, $6.14 per foot, no earthwork included.

Sixty inch.—At Pueblo, Colo., 1907; on 17 fir pipes the unit price per foot ranged from $4.19 to $6.58, averaging $5.51. The combined length of 17 pipes equals 19,821.5 feet, making the average price per foot on this basis equal $6.27; earthwork not included.

Sixty inch.—At Nissa, Oreg., 1912; 6,700 feet; average head about 65 feet; bands, ⅝ inch diameter; staves, fir, 2 by 6 inches; built on wooden cradles; contract price, $4.25 per foot, included material, erecting, and freight, but no haul or earthwork.

Eighty-four inch.—At Pueblo, Colo., 1911; 18,000 feet; maximum head, 70 feet; fir staves, 2⅝ inches thick; bands, ⅝ inch diameter; maximum spacing, 10 inches; minimum, about 4 inches; contract price, $6 per linear foot, including everything except hauling and earthwork. Line very crooked, with 14 vertical curves. Much of it is about one-half in ground. Total cost of line was about $9 per foot, everything included.

Fir staves at Seattle, Wash. (December, 1912), were quoted at $30 to $32 per thousand feet b. m., according to size, etc. They take the same freight rate as lumber of the same class. Redwood staves at San Francisco were quoted at about $45 per thousand. The price of malleable iron shoes, at Marion, Ind., was approximately $3.75 per hundredweight on lots of from 1,000 pieces to a carload, with an additional charge of 10 cents per hundredweight if dipped in rust-proof paint. Drop forged steel shoes 3½ inches long were quoted at 2¾ cents to 3½ cents each at Ballard, Wash., and 5-inch shoes at 3½ cents to 4 cents each.

Bands made at Pueblo, Colo., were quoted f. o. b. Spokane, Wash., at $2.97 per hundredweight for carload lots, 10 cents per hundredweight additional being charged if required to be bent and dipped.

Steel tongues are quoted at the same prices as bands.

Pipe coating of a well-known brand used as a dip for bands was quoted at $57.50 per ton f. o. b. the Chicago factory.

MACHINE-BANDED PIPE.

Machine-banded pipe is being very extensively manufactured on the Pacific coast and at several points in the Eastern States. The principal factories of the West are at San Francisco, Cal.; Portland, Oreg.; Tacoma, Wash.; Seattle, Wash.; and Vancouver, B. C. Other factories are at Elmira, N. Y.; Bay City, Mich.; Williamsport, Pa.; and Alexandria, La.

Redwood is used for the pipe made at San Francisco, while fir is used exclusively at the other western points mentioned. The eastern factories use white pine and tamarack, principally, for water pipe, and hard maple, beech, and birch for special mining purposes. In Louisiana, water pipe is made from cypress, which wood is used also for steam-pipe casing.

The original machine-banded pipe consisted of logs turned in a lathe, machine bored, and then wound with continuous flat steel bands. Pipe of this type in sizes from 2 to 6 inches in diameter is still manufactured in Michigan, but most of the machine-banded pipe is now made up of staves, the sections ranging in length from 8 feet to 12 feet in the East, and to 20 feet in the West. Diameters run from 2 inches up to 48 inches. Western factories, however, build little pipe of this kind more than 24 inches in diameter.

The thickness of the staves varies to some extent. The redwood pipe in usual sizes is about 1 inch thick and the fir pipe $1\frac{1}{4}$ inches. The eastern pipe is usually $1\frac{5}{8}$ inches thick, while for pressures of 40 pounds or more and in sizes from 24 inches up, the shell of some of it is made 3 inches thick.

Galvanized steel wire is used exclusively on the Pacific coast for banding. The size of the wire varies from No. 8 to No. 0, and the closeness of wrapping is regulated according to the pressures for which the pipe is designed. These may range from very low heads up to 400 feet or more. The eastern factories band their pipes with hot rolled steel 14 or 16 gauge, 1 inch wide, and No. 16 and No. 18 gauge, $1\frac{1}{2}$ inches wide. The banding is done with a machine which imposes on the steel a tension sufficient to make a very tight contact with the wood, and may even indent the staves somewhat where wire is used. The ends of the bands are secured with staples or clips.

After the pipe is banded and the ends are milled for couplings, each section is dipped in a hot asphaltum preparation which thoroughly coats the bands and exterior of the pipe, then it is rolled in sawdust or shavings to form an outer covering, which renders it more agreeable to handle.

COUPLINGS.

Couplings for machine-banded pipe are of several types. Of these one of the commonest is the "inserted joint." To make this coupling a tenon is milled on one end of a section of pipe and a mortise on the other, so that the connection is made by simply inserting the tenon of one section into the mortise of another and driving together. In the western pipe this form of coupling is used principally for low pressures. Where greater strength is required reinforcement may be applied to this joint by using individual bands. For another form of coupling tenons are made on both ends of each section of pipe, and with each joint a wooden stave collar or sleeve is used, into which the tenons are inserted. These collars for small pipes are machine banded the same as the pipe, but for the larger sizes individual bands are used. Collars of riveted steel or iron were used with such pipe in the earlier days of its manufacture on the Pacific coast, and cast-iron collars have been employed also in many places. The latter material is still used for bends, crosses, tees, reducers, and other specials, but for collars it has been almost wholly supplanted by the other forms mentioned. The wooden collars are cheaper, but because they often decay quickly are much inferior to those made of iron.

USE OF MACHINE-BANDED WOOD PIPE.

Machine-banded wood pipe has had its most extensive use in the Pacific coast and Rocky Mountain States for municipal waterworks systems, where there is scarcely a city or town of any consequence

but what has at some time put in more or less of it, and the demand for this purpose continues to require a large output from the factories. It is also used a great deal in conveying water supplies for manufacturing purposes and fire protection for factories and mills, for railway tanks, for power plants, hydraulic sluicing operations, etc., and during recent years there has been a great deal of it used for irrigation purposes, particularly in the Northwestern States. In the East it is used to some extent for municipal water supplies, considerably for various purposes in the mining regions, and for oil conduits, insulated wire conduits, steam pipe casing, etc.

For municipal waterworks the low first cost of machine-banded wood pipe as compared with that of cast iron or steel pipe has in most instances been the consideration leading to its use, and many communities which now have an abundance of water for domestic purposes, fire protection, etc., would still be unsupplied had not some such cheap type of pipe been available.

While possessing some advantages other than that of low first cost, machine-banded pipe, according to the experience of many localities, has been found inferior in many respects to cast iron and steel for city mains and connections. The complaint most frequently expressed with reference to its use for this service relates to trouble arising from leaks, which occur mainly at the joints. Such leaks may develop as the result of decayed collars, from carelessness in putting the pipe together, from increasing the pressure above that for which the pipe was designed, or from other causes. While in many cases even a considerable leakage may be permissible, in others any material loss is highly objectionable. Leaks are particularly objectionable where pipes are located in paved streets, and owing to the difficulty in avoiding leaks, as well as because its life is usually shorter than that of metal, wood pipe is usually replaced before paving, and in the larger cities its use for distributing systems is now being very generally discontinued.

For service of a more or less temporary nature, such as hydraulic sluicing, dredging, etc., where absolute tightness is not essential, but where low cost, ease of transportation, facility of putting together, removing, and relaying at small expense are desirable considerations, machine-banded wood pipe is peculiarly well adapted.

The use of machine-banded wood pipe in connection with irrigation work is confined to the West, particularly the Northwest, where hundreds of miles of it have been installed for delivery pipes of small pumping plants, for inverted siphons, etc. In a number of places the entire water supply is conveyed through such pipes, delivery being made to each unit of area, often as small as 5 acres or less. And beyond this, many farmers use wood pipe instead of

head ditches or flumes, tapping it and inserting small hydrants at the head of each tree row or at closer intervals.

These hydrants usually consist of three-fourths-inch galvanized-iron pipe which is screwed into the shell of the wood pipe, and equipped with a cheap valve for regulating the discharge. The cost of such outlets, including the threaded nipples 18 inches long and the valves, is about 40 cents each.

The conditions of irrigation service are in perhaps a majority of cases unfavorable to a long life of this kind of pipe, and where the pipe is empty for several months out of the year decay is often very rapid, but except for this disadvantage no substitute has been found which meets so many of the other requirements of irrigation service.

COST OF MACHINE-BANDED WOOD PIPE.

The cost of machine-banded wood pipe varies with the head for which it is made, fluctuations in the market prices of materials, the kind of wood used, etc., and will differ also in accordance with freight or transportation charges from the factories to different points.

The following prices f. o. b. cars at Seattle, Wash., quoted for estimating purposes only, will give some idea of the present prices of fir pipe, and from the weights given the freight charges to any point may be ascertained by consulting railway rates. A minimum carload is 30,000 pounds.

Table showing prices and weights per linear foot of machine-banded wood pipe, f. o. b. cars, Seattle, Wash.

Diameter.	Head.	Price.	Weight.	Diameter.	Head.	Price.	Weight.	Diameter.	Head.	Price.	Weight.
			Pounds.				*Pounds.*				*Pounds.*
2-inch.....	50	$0.087	3.1	10-inch...	50	$0.268	13.1	18-inch...	50	$0.597	26.9
	100	.090	3.2		100	.347	14.7		100	.750	30.8
	150	.092	3.2		150	.392	15.7		150	.884	34.6
	200	.100	3.4		200	.455	17.3		200	.992	38.0
	250	.105	3.5		250	.479	18.4		250	1.266	45.6
	300	.116	3.6		300	.503	19.4		300	1.528	54.8
4-inch.....	50	.129	5.8	12-inch...	50	.322	16.8	20-inch...	50	.655	29.6
	100	.131	5.9		100	.413	18.9		100	.828	34.4
	150	.134	6.0		150	.450	19.8		150	1.033	40.0
	200	.166	6.3		200	.532	21.7		200	1.192	44.0
	250	.176	7.0		250	.618	23.8		250	1.428	52.0
	300	.189	7.3		300	.660	25.3		300	1.615	57.5
6-inch.....	50	.163	8.3	14-inch...	50	.445	21.3	22-inch...	50	.773	33.9
	100	.168	8.9		100	.550	23.0		100	.990	40.1
	150	.184	9.1		150	.629	25.3		150	1.184	45.2
	200	.226	9.6		200	.745	28.2		200	1.415	52.7
	250	.242	10.0		250	.834	29.9		250	1.710	59.8
	300	.258	10.4		300	.916	32.3		300	1.845	65.5
8-inch.....	50	.203	10.3	16-inch...	50	.547	24.7	24-inch...	50	.855	37.3
	100	.224	10.5		100	.639	26.9		100	1.075	44.0
	150	.292	12.8		150	.734	29.3		150	1.334	51.0
	200	.332	13.7		200	.871	33.4		200	1.627	59.3
	250	.366	15.6		250	.987	36.2		250	1.934	67.8
	300	.387	16.2		300	1.132	40.2		300	2.100	74.3

The cost of wood pipe is in most places materially less than that of cast iron or steel, though direct comparisons are difficult to make. At the time the waterworks were built at Astoria in 1895, Mr. Adams

estimated that the use of wood effected a saving of 43 per cent over steel pipe of similar size, No. 12 gauge, and nearly 50 per cent over one of equivalent carrying capacity. In discussing the waterworks of Denver, in 1894, J. D. Schuyler states:

At a moderate estimate the saving effected by the Citizen's Water Co., by the use of wooden pipe for their main conduits has been no less than $1,100,000 over the cost of cast-iron pipes of equal capacity. The interest on this amount at 6 per cent would renew the mains every five or six years, or duplicate them as often as that if necessary.

S. Fortier[1] gives the bids for supplying material and laying the following pipes at Salt Lake City, Utah, in 1900: 30-inch stave pipe, $2.95 and $3.10; 30-inch cast-iron pipe $10.20 and $10.85; 30-inch riveted steel pipe, $8.65 and $9.15; 24-inch stave pipe at $2.60 and $2.55; 24-inch cast-iron pipe, $7.45 and $8.15; and 24-inch riveted steel pipe, $5.75 and $6.05.

At Spokane, Wash., the relative prices for small pipes are about as follows:[2] 6-inch wood pipe, 25 cents per linear foot; 6-inch steel pipe, 63 cents per linear foot; 6-inch cast-iron, 72 cents per linear foot.

The price per ton of cast-iron pipe at Spokane is about $43 (1913), and somewhat less at Pacific coast points.

LAYING MACHINE-BANDED WOOD PIPE.

Laying machine-banded wood pipe is a very simple operation, and as no calking of joints is required it may be done by unskilled labor. Nevertheless, much dissatisfaction in the use of pipe of this kind may result from carelessness in handling and laying.

In shipping from the humid Puget Sound region to the arid or semiarid districts east of the mountains wood pipe may shrink very materially if allowed to lie exposed to the sun and wind for any considerable time, and for this reason it should be protected from such influences so far as possible before laying. Otherwise it may be difficult to get the pipe tight after water is turned in. Care should be exercised in handling the pipe, so as to avoid bruising or in any way injuring the tenon ends. The tenons should be carefully examined as the pipe is being put together, and, in case bruises or scratches occur, the section should be turned so that the injury will be on top where it can be easily plugged if a leak should develop.

Pipes up to 4 inches in diameter may be driven together with a maul, a tampion being used to protect the end of the pipe. Pipe 6 inches in diameter and larger can best be driven with a ram which

[1] U. S. Geol. Survey, Water Supply and Irrig. Paper 43, p. 71.

[2] Ann. Rpt. Water Div., Dept. Public Utilities [Spokane, Wash.], 1911.

may be made of a heavy piece of timber about 5 feet long. The pipe is usually driven from the coupling or mortised end.

Deflections of from 2° to 6° per joint can be made with this kind of pipe, but a straight line is desirable, and crooks in either vertical or horizontal alignment should be avoided as far as possible. Where curves are necessary, short sections of pipe may be obtained for the purpose. Greater deflections can be made with small pipe than with large sizes.

The backfilling around curves should be thoroughly tamped or puddled, as a precaution against blowing out under pressure, and metal bends and plugs should also be well staked or reinforced, for the same reason.

To make best progress in laying this kind of pipe a crew of from four to eight men is required, the number depending on the size of the pipe. The amount that can be laid in a day varies with the size of the pipe, experience of the crew, and other conditions.

The Pacific Coast Pipe Co. estimates the cost of laying western pipe at from 1½ cents per foot for 4-inch to 5 cents per foot for 24-inch, exclusive of all distribution along ditch and earthwork. The Portland Wood Pipe Co. estimates the cost of laying different sizes as follows: 4-inch, 1 cent per foot; 6-inch and 8-inch, 1½ cents; 10-inch, 2 cents; 12-inch, 2½ cents, distribution and earthwork not included. P. A. Devers, manager Pasco Reclamation Co., Pasco, Wash., gives the cost of laying pipe at Pasco, as follows: For sizes from 8 inches to 14 inches in diameter the labor cost for excavation and installation varies from 8 cents to 10 cents per linear foot, according to size. Trenches for some of the larger pipes were excavated by contract at 25 cents per cubic yard. For installing several miles of 6-inch pipe, the trenching and other labor cost was about 6 cents per linear foot. The rate of wages is not given, but presumably laborers were paid from $2 to $2.50 per day of 10 hours. Trenches were probably not more than 2 feet deep, and the material excavated was mainly a sandy soil. In gravel the cost was increased 15 to 20 per cent, according to the statement of Mr. Devers.

MAINTENANCE OF WOOD-PIPE LINES.

It should not be assumed that large continuous stave pipe lines when once installed will forever after take care of themselves. Reasonably frequent inspection is advisable, and whenever leaks are found, or injuries of any nature are sustained, they should be repaired without unnecessary delay. Negligence in this respect and failure to appreciate the importance of such inspection has not only shortened the life of many pipe lines, but has in some instances greatly increased the cost of repairing. The continued impinging of a grit laden jet from a small leak has been known to sever steel

bands five-eighths of an inch in diameter, while the failure of a section of machine-banded pipe due to the wire being cut in this way is not uncommon.

Small leaks at the joints or seams of wood pipe are usually stopped with wooden wedges. In the case of leaks around the wooden couplings of machine-banded pipe, the wedges are driven into the staves of the coupling sleeve, and not between them and the pipe. If a section of machine-banded pipe or a collar fails on account of the cutting of the wire, individual bands with coupling shoes similar to those used for the large continuous stave pipe can be obtained for making repairs. An assortment of these might well be kept on hand where likely to be needed.

The repairs of a large pipe may call for considerable ingenuity and unique methods. When several five-eighths-inch bands of the 48-inch Mabton (Wash.) siphon were cut by a leak, allowing the ends of two staves to spring out and break off, a diver was employed to make the repairs. At the bottom of the Yakima River, 15 to 20 feet under water, steel plates with gaskets, one on the inside and one on the outside of the pipe, were clamped together with bolts so as to stop the leak.

Under ordinary circumstances the repair of continuous stave pipe is not difficult. The removal and replacement of staves or portions of them is a matter of frequent occurrence. It is only necessary to remove a few bands, take out the defective stave, spring another into place, and reband. If the pipe has been buried and the threads on the bands have become badly rusted, as they frequently do, any change in the position of the nut may necessitate the use of a new band, though if the body of the band is fit to be used again a new thread may be welded on. This has been done by the Butte Water Co.

Where a pipe is above ground any landslides coming in contact with it should be cleared away as a precaution against decay, particularly if it is at a point where the pipe is under light pressure. If supported in cradles, mudsills or footings should be renewed as decay progresses, in order to avoid injury to the pipe from settling. Weeds permitted to grow along an exposed pipe may, when dry, be a source of danger from fire, and on this account if for no other reason they should be kept down so far as conditions will warrant.

On many irrigation systems it is necessary to empty the wood pipes in the fall, as a precaution against damage from freezing. Where this is the case they should be kept full as late as possible, and be filled again in the spring just as soon as conditions will permit. In some instances irrigation managers close the inlets and outlets of wood pipes when emptied in the fall, so as to prevent the

circulation of air and the consequent drying of the wood during the winter.

In the operation of pipe lines, especially irrigation "siphons," conditions frequently favor the admission of air, which may very materially reduce the carrying capacity, and sometimes it is sufficient to cause pulsations or vibrations so violent as to be a menace to the life of the pipe. This difficulty is usually remedied by the introduction of air vents at the top of the pipe near the intake, carrying them back up along the pipe itself, or perhaps to one side of the line to a point above the hydraulic gradient.

The cost of maintenance in the operation of wood pipe lines varies greatly. In many instances where there has been a careful selection of materials, good construction, and favorable conditions of service, the expense of maintenance may be for many years an almost negligible amount, while again, where the above conditions do not obtain, the cost for repairs and upkeep may be considerable. It is usually less during the first few years than it is later on in the life of a pipe.

A. P. Merrill, manager of the Utah Power Co., in connection with his experience in operating a number of pipe lines aggregating 10 miles or so in length, writes as follows:

The maintenance of pipe lines depends, of course, on the manner in which they are constructed. At this time I have no definite maintenance costs which can be given to support any statements that I might make. In general, however, I should say that a wood pipe line properly constructed with Kelsey joints and laid under sufficient pressure requires practically no maintenance, at least during the first 10 years. We have had comparatively new lines, however, where the construction was somewhat faulty in some respects, and where the butt joints were not used, which require more or less maintenance work during each year.

Eugene Carroll, manager of the Butte Water Co., in writing concerning the pipes built at Butte in 1892, 1899, and 1900, makes the following statement:[1]

The pipe connects our reservoirs, one 13 miles and the other 22 miles out, with our reservoirs in town. The watchman, which we have to keep at each reservoir, makes a trip over the pipe line once a week. Occasionally in making these trips it is necessary to dig out the pipe for small leaks, such as worm holes on butt joints, but with two exceptions we have never had to use more than two men in repairing leaks, and have never had to shut off the water. Our two exceptions are, first, during the winter of 1893 ice formed inside of our pipe line, being caused from the fact that our reservoir was not completed, and a jam was caused inside the pipe, bursting it, requiring the shutting off of the water and about 12 hours to repair it. Last spring on our new pipe line a leak developed near one of our valve chambers, and before it was discovered and the water shut off a bad washout took place, which washed the supports away from the pipe line for about 1,000 feet, necessitating the rebuilding of the line, taking about four days to do it.

[1] Trans. Amer. Soc. Civ. Engin., 58 (1907), p. 73.

Writing again seven years later, Mr. Carroll repeats that one man on each of these lines is all the labor required, the inspections being made about once a week, and he says:

I attribute our low cost of maintenance to the careful and frequent inspections we make of the lines.

The cost of repairs on the 12 miles of conduit at Astoria, Oreg., for 10 years after its construction is given by A. L. Adams as follows:[1]

Cost of repairs on 12 miles of conduit.

Year.	Cost.	Year.	Cost.	Year.	Cost.	Year.	Cost.	Year.	Cost.
1895	$108.58	1897	$63.67	1899	$46.10	1901	$243.18	1903	$350.18
1896	15.90	1898	65.50	1900	71.59	1902	314.03	1904	895.10

The foregoing figures include the expense of repairing the damage resulting from two landslides. Aside from this, most of the cost was charged to the 7½ miles of wood pipe. The total cost of repairing 27 perforations which occurred in the steel pipe in 1902, 1903, 1904, and 1905 was $297.

For repairing staves in 48-inch pipe near Clarkston, Wash., in January, 1912, R. A. Foster, engineer and manager, Clarkston system of Lewiston-Clarkston Improvement Co., gives the following detailed cost data:

	Cents.
Milling staves	3.04
Hauling, 182 ton-miles, at 37.09	18.24
Removing old pipe	3.24
Repairing old bands	2.43
Subdelivery of material	5.77
Laying	9.12
Replacing bands, 555, at 8.11 cents per band	12.16
Cook	3.04
Food, 71 cents per ration	13.42
Lost time of men	4.73
Lost time of team	1.92
Piling of old lumber saved	1.73
Superintendence	4.83
Cost of lumber, $28 f. o. b. Lewiston	81.20
Total	164.87

Making total cost per foot, $1.65.

Wages of men, 25 cents per hour.

[1] Trans. Amer. Soc. Civ. Engin., 58 (1907), p. 69.

For replacing 280 feet 40-inch pipe, January, 1911.

Item.	Cost.	Cents per foot.
Hauling staves, 78 ton-miles, $37.30	$29.30	10.4
Excavating and tearing down	41.00	14.4
Relaying	81.90	29.3
Superintendence	30.00	10.7
Piling old lumber	9.00	3.3
Lumber, 6.7 M., at $28	187.60	67.0
Total	378.80	135.1

DURABILITY OF WOOD PIPE AND FACTORS AFFECTING IT.

"How long will it last?" is a question asked perhaps oftener than any other in the discussion of wood pipe. It was the common question during the early years of its manufacture, and it is common to-day after the experience of more than 30 years of extensive use.

The failure of wood pipe is in general due either to decay of the wood or corrosion of the bands, though wearing out of the wood is also under certain conditions a matter upon which the life of a pipe may depend. The range of variability with reference to these points in the life of the pipes that have been built has been such as to demonstrate conclusively that how long any pipe will last can not be accurately predicted without a thorough knowledge of all the conditions involved.

Sufficient time has not yet elapsed to show the life of some of the earliest continuous stave pipes that were built, while others have endured but from 5 to 12 years. In support of the foregoing statement specific data bearing upon the durability of a number of pipe lines, several of which were inspected by the writer, are given in the following pages.

In writing of the first continuous stave pipe built in the West, at Denver, in 1884, S. Fortier states[1]—

> The pipe was laid in a portion of its length about 15 inches above the hydraulic gradient. Native pine, whose durability under unfavorable conditions is from three to five years, composed the staves, and in the portion of the line referred to the pipe was never more than two-thirds full of water. The top staves decayed rapidly. In the fall of the year (1889) the Denver Water Co. had bands loosened and the staves from the upper arc removed without shutting off the water. It was then found that the lumber was perfectly sound up to the surface of the water in the pipe, and in the next stave above on either side, whereas the remaining staves which the water could not reach by capillary attraction or otherwise were rotten.

A part of this line, lying close to the river, under conditions where both exterior and interior are kept wet, was said to be still in use in 1912.

[1]Ann. Amer. Soc. Irrig. Engin., 1892–93, p. 11.

In 1886–87 the next important pipe line of this kind was built from Cherry Creek crossing to Denver. Some of this lasted until 1907, when it was replaced by a 30-inch fir pipe. The original line consisted of about 7¾ miles in all, of 37, 30, and 24-inch pipe, the material being about two-thirds western yellow pine (*Pinus ponderosa*) and the remainder redwood.

In 1890 a 30-inch pipe was completed from the Platte Canyon to Ashland Avenue, Denver, about 21 miles; 16.4 miles of this line is wood—Texas pine and California redwood. It is still in use. In the spring of 1890 a 24-inch redwood pipe 5½ miles in length was built at Ogden, Utah. In 1911, 4,674 feet of this line was replaced, but is still used as an overflow pipe from a reservoir. On a few summits, where not always full, the pipe has decayed badly, but with these exceptions the original line is in general very well preserved. When inspected in October, 1912, repairs were being made at a river crossing, where settling of the bridge had caused the splitting of many staves, which were being replaced. These staves were not rotted materially, but about one-eighth of an inch of the interior was so softened that it could be easily scraped off with a knife. Many of the staves were also split back from the saw kerf several inches, thus permitting the outer portion to decay more rapidly than the rest of the stave. This portion of the pipe at another point, where supported on a trestle protected from the sun by rough boards, showed the staves to be in a perfect state of preservation. The pressure at the latter point was light, as indicated by the spacing of bands, which were 1 foot apart.

A 48-inch redwood pipe, 2,000 feet long, built by the Bear Valley Irrigation Co., at Redlands, Cal., in 1891, was in continuous use until the summer of 1912, when it was replaced by a ditch. About 500 feet of this pipe at the upper end was completely buried, and of the remainder of the line which was originally supported 200 to 300 feet became partially covered by slides from the slopes. Where in contact with the earth the staves of the pipe were considerably decayed, but in other parts the wood was well preserved at the time of its removal.

In 1892, 48,193 feet of 24-inch redwood pipe was built for the Butte (Mont.) Water Co. Eugene Carrol, manager of the company, under date of January 15, 1913, states:

> During the past season we had occasion to open this pipe to make a new connection at the lower end and found it in excellent condition. As far as we know, the whole line is in excellent condition, and there has been no deterioration noticeable. Of course, the bands are rusted considerably, and when it is necessary to remove a band a new one has to be substituted. At one point where earth was hard to get we backfilled with broken rock, which allowed the air to get to the outside of the pipe. It is our experience that this caused the deterioration of the wood, and the broken rock was removed and replaced

with sand and earth, carefully tamped around the pipe. This apparently stopped the decaying of the wood. The Basin Creek line has now been in service 20 years, and it is impossible to estimate how much longer it will last, as at present it has shown no signs of giving out.

An 18-inch redwood pipe 8,600 feet long was built at Logan, Utah, also in 1892. This is still in service, but its condition is not known, though presumed to be good.

Roswell Snow, superintendent of waterworks, Provo, Utah, under date of January 30, 1913, writes as follows concerning a redwood pipe:

I have been in touch with this pipe for the past eight years, and have been taking note of it in the different ground in which it is laid. I find in the clay ground it seems to be nearly as good as new, in gravelly ground it is in fairly good shape, but in loam and light soil it is nearly gone. It has been in use nearly 25 years and I would think that the pipe in the clay ground would last 20 years longer.

In the years from 1897 to 1901 and 1902, the Union Hollywood Water Co. at Los Angeles, Cal., installed continuous stave redwood pipe, which, according to F. C. Finkle, consulting engineer, who examined it in 1910, was rotted to a mere shell from one-sixteenth to three-sixteenths of an inch thick. This was in a gravity system under a head of not to exceed about 50 feet and in places considerably less. He states that of another redwood pipe installed at Long Beach, Cal., in 1900, 4,000 feet or so was replaced in January, 1912. This, under his observation from 1908 to 1912, was found to be badly decayed, and the bands were seriously corroded, though none failed. It was laid in a compact soil which contained some alkali. The pressure ranged from 20 to 40 pounds.

In the fall of 1895, 7½ miles of fir pipe was built at Astoria, Oreg.[1] In 1905 portions of this line were found to be badly decayed, and in 1911 it was all replaced by another pipe of redwood.

G. W. Lounsberry, of the Astoria Water Commission, states:

Where the line was buried to a depth of 2 feet or more in fine-grained sand or clay it lasted much better than where it was laid in black soil mixed with decayed vegetation or where it was laid in shale. This, regardless of the water pressure, and the staves in the bottom where there was a constant flow of water were equally affected with those on top that at times were dry on account of the pipe not running full.

The 72-inch fir pipe, 3 miles in length, built for the Pioneer Electric Power Co. at Ogden, Utah, in 1897 is still in service. Repairs in the nature of an occasional new stave have been necessary for several years, and in the month of October, 1912, when it was inspected, arrangements were being made to replace the upper end where the pressure is light. This pipe is in many places but little below the hydraulic gradient and in most parts but lightly or partially covered.

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[1] Trans. Amer. Soc. Civ. Engin., 36 (1896), p. 1; 58 (1907), p. 65.

At one point some distance below the intake where uncovered for repairs, the staves of the lower half of the pipe were found to be decayed to a mere shell. The 4-inch spacing of bands indicated a fairly good internal pressure. The backfill was stony. Near the dam, where the pressure was not more than 10 or 15 feet, the staves were badly decayed, and it is probable that much of the pipe was in poor condition at this time. On a bridge where it had always been fully exposed there was no appreciable decay of the staves other than at leaky joints, and the same was true along the top of the pipe where exposed or covered with only an inch or two of coarse soil, which permitted it to remain dry.

R. M. Hosea, chief engineer of the Colorado Fuel & Iron Co., writes as follows about a pipe several miles long:

> The oldest line we have—28 inches in diameter—was built in 1900. For five years past it has been repaired in places by inserting new staves where old ones were badly rotted on the exterior. This allows bands to sink into soft wood and staves to leak. The rot progresses until one-half to three-fourths of the wood is rotted. It occurs in patches, or on certain staves their full length, according to amount of pitch in the wood, or some variation in its quality. This pipe was of Texas pine staves. I should add also that the bands become rapidly corroded where leaks have formed and ground is moist, and I should doubt a life of 20 years for this line even if repairs are kept as above indicated, where we are constantly putting in new fir staves and some new bands.

This pipe is laid in fine adobe soil and covered to a depth of 2 feet or more.

By the side of the pipe just mentioned, and under the same conditions, a 48-inch fir pipe was laid in November and December, 1906. Mr. Hosea says that in three years it was decayed sufficiently to cause leaks. When inspected in October, 1913, it showed serious decay, and was being incased with reinforced concrete. This pipe was covered with the adobe soil from 18 inches to 2 feet deep, and where examined was under a head of perhaps 30 feet or more. In most instances the decay extended half way through the staves. Sometimes a sound stave occurred, while those on each side of it might be badly rotted. The bands were in good condition and only slightly corroded. Twenty-five other pipe lines built by this company about the same time as this one have also been incased with concrete, decay in the case of each having made more or less progress.

Under date of May 15, 1912, L. B. Youngs, water superintendent of Seattle, Wash., writes as follows:

> The first wood pipe that we installed in this city was put in 12 years ago, and was made out of our native timber here, known as Douglas fir. * * * In clay soils the pipe lasts fairly well, and I would place its life at from 12 to 20 years; in sandy and gravelly soils I would place its life at from 7 to 12 years. However, in the case of large pipe with individual bands the cost of reinstallation would be the cost of the wooden part of the pipe only, as we find the iron bands to be in good condition after 10 to 12 years' service, so that they could be used for the new wood.

In 1901 the National Sugar Manufacturing Co. at Sugar City, Colo., built about 4 miles of fir pipe, which was covered by earth to a depth of 2 to 4 feet. The one-half inch steel bands began to give way after six years, more of them each succeeding year, causing frequent breaks in the line and much annoyance, especially in winter. In 1910 this line was rebanded with $\frac{5}{8}$-inch round, refined bar iron.

A 24-inch fir pipe 3 miles long was built for the Pueblo (Colo.) waterworks in 1904. This was banded with one-half inch soft steel bands, buried from 1 to $3\frac{1}{2}$ feet deep, a part in shale, and some in an adobe loam soil. About seven or eight years later the bands began to fail. Four thousand feet of this pipe was replaced in 1912, and the remainder was taken up in 1913.

The foregoing examples are all continuous stave pipes, but an investigation of the life of machine-banded pipe shows a like variability, the length of service being dependent altogether upon conditions. Instances are frequently published illustrating the extremely long life of the old bored log pipes which were used in the early days, and there is probably a considerable amount of machine-banded pipe which under favorable conditions has now been in use for 30 years or more, while in a great many places the conditions of service have been such as to render the life very short.

A. F. Doremus, of Salt Lake City, Utah, states that flat-banded bored pipe laid for the city water system of Tooele, Utah, in 1890 is still generally in good condition, except in places where it was not kept wet. This system now consists of about 20 miles of wood pipe, much of which is of the modern machine-banded stave type. Some of the modern pipe has had to be replaced in three years. A great many instances might be cited where the life of machine-banded pipe has been only from 4 to 10 years. Based upon the experience in Spokane, Wash., the life of machine-banded wood pipe is given as ranging from 4 to 12 years.[1] Such short life in most instances is probably due to bad judgment in the matter of location or the use of pipe under conditions altogether unfavorable to its life.

Frequently in connection with municipal water systems pressures are imposed far in excess of those for which the pipe was designed, thus hastening its destruction. For irrigation systems the demand by some of the promoting companies for an extremely cheap pipe without particular consideration as to its durability has probably in some instances led the manufacturers to incorporate poor material in the pipe supplied.

The unfavorable conditions of whatever nature, singly or together, result most frequently in the decay of the pipe, thus shortening its life. The decay of wood pipe is probably due primarily to the

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[1] Ann. Rpt. Water Div., Dept. Public Utilities [Spokane, Wash.], 1911.

growth of fungi, though possibly certain forms of bacteria may assist in the final destruction of the wood cells. The growth of fungi to an extent detrimental to the life of the wood requires a favorable combination of moisture, air, and heat. The exclusion of any one of these beyond certain limits inhibits their growth.

From this it follows that with pipes buried in the ground the wood will endure longest where the air is most nearly excluded either by a high internal pressure which completely saturates it or by a deep covering of very fine soil. In accordance with the foregoing statement, experience, which might be illustrated by many specific examples, shows that in contact with the soil wood pipe decays more rapidly under a light head than it does under heavy pressure, and other things being equal, it usually decays more rapidly in a porous open soil, such as sand or gravel, than it does in a fine soil of silt or clay, because the finer soil is more effective in excluding the air. Experience appears to indicate also that wood decays more rapidly in a loamy soil, rich in humus or partially decayed organic matter, than it does in one containing little or none. This is probably due to the fact that the presence of organic matter affords more favorable conditions for the development of fungus growths and bacteria.

Pipes fully exposed to the atmosphere and free from contact with the soil will, as a rule, be too dry on the exterior to favor the development of fungus spores, and so long as the outside of a pipe remains dry no appreciable decay will occur, even though the internal pressure is very light. Decay of exposed pipes almost invariably starts at the ends of staves, as a result of leaky joints. Where water leaks out and runs down over the outside of the pipe favorable conditions are afforded for the growth of algæ, which usually get a start, then mosses may begin to grow in the soil that collects on such spots, and decay spreads to adjoining staves. Bruising the staves in handling or injuring by too tight cinching of bands renders them more susceptible to infection by the spores of wood-destroying fungi, thus hastening decay. The life of exposed pipes may be prolonged by promptly stopping all leaks as they develop and by keeping the exterior dry. The decay of buried pipes has also in some instances been arrested by removing the covering and leaving them exposed.

The asphaltum or tar coating applied to machine-banded pipe, while intended primarily as a protection against corrosion of the bands, doubtless helps also to some extent in preserving the wood. Until recently the practice has been to leave the ends of wooden sleeve couplings untreated. These couplings almost invariably decay long before the main pipe. This may indicate that infection by wood-destroying organisms starts principally where the coating is absent, though less perfect saturation of the wood in the sleeves may be the more largely responsible for the early decay, as it may be noted

also that decay occurs at summits of pipe lines where air accumulates much sooner than at depressions.

The practice of coating continuous stave pipe has not been common, but in a considerable number of cases some treatment has been applied for the purpose of preserving the wood. There is wide difference of opinion as to the value of such treatment, and the effectiveness for the purpose intended may depend also greatly on what is used and upon how and when it is applied.

On exposed portions of new pipes the United States Reclamation Service has used a paint consisting of 6 pounds of red oxid mixed with 1 gallon of boiled linseed oil. One gallon of the paint was sufficient for two coats on 125 square feet of pipe. On top of the pipe where exposed to the sun and where water from leaky joints runs down over it this paint does not last long, much of it being gone in two years. Repainting while the pipe is in use is usually not practicable, because oil paint will not adhere readily to wet material. The use of paint on exposed pipes under ordinary conditions probably adds very little to their life.

The Denver Union Water Co. on new work in 1911, used a primary coat of linseed oil and lampblack, and a secondary coat consisting of an asphaltum mixture. In March, 1914, the "Mabton siphon," which had been uncovered the fall previous on account of decay, was given two coats of coal tar tempered with creosote. The mixture was applied by a machine which pumped the hot mixture through a hose and nozzle, shooting it on to the pipe with considerable pressure. The same machine was used in cleaning the soil and decayed material from the pipe before painting. Other instances might be cited showing the use of asphaltum or tar on old pipes after uncovering. The cost of the work is considerable and its value is questionable, particularly where pipes are to remain exposed.

The staves of a 50-inch pipe built at Burbank, Wash., December, 1912, were creosoted before construction. This pipe was buried in sandy soil and operates under little or no internal pressure. The cost of treating the staves was said to be $24 per thousand. Carbolineum was used as an exterior coating on part of a 48-inch pipe built at Wenatchee in 1907, and on a 12-foot pipe built in Oswego County, N. Y.

Where pipes are to be placed in contact with the soil, and where the internal pressure is not sufficient to insure complete saturation of the staves, it is probable that their durability may be increased by treating with some preservative.

A difference in the effectiveness of materials for this purpose is indicated by the following example: In 1890 a 54-inch pipe of Texas pine was built for the Bessemer Ditch Co., at Pueblo, Colo. About 1,500 feet of this was subjected to light pressure, and at times the pipe

was only partially filled. This portion was badly decayed in five years, and 1,100 feet of it was replaced by redwood in 1895. With the exception of a 100-foot section near the middle of the new part, the redwood was painted with hot coal tar. The 100-foot section was painted with asphaltum paint. According to Mr. C. K. McHarg, secretary of the company, the pipe coated with tar was found to be perfectly sound when examined in 1910, while the 100-foot section was badly decayed and had to be replaced.

Contrary to the theories commonly held 30 years ago, it has been found that the durability of wood pipe is usually dependent on the life of the wood rather than on the life of the bands. Only in rare instances, some of which have been cited, have the bands failed first. Corrosion of the bands being a chemical action, requires the presence of moisture and oxygen. It usually occurs most rapidly where pipes are buried and the backfill is wet, under conditions which, as a rule, are most favorable for the life of the wood. Corrosion is greatly accelerated by the presence of alkali in the soil. The early failure of bands in the few instances cited was due chiefly to this cause. Under such conditions the bands almost invariably fail at the bottom of the pipe.

Wearing out of the wood as a factor in the durability of pipe is a matter of small consequence, though it must at times be recognized. A 48-inch spruce pipe on the Catlin Canal in Colorado, in 23 years' use, was worn nearly through the staves for a distance of nearly 100 feet at the outlet end. The inlet end of a redwood siphon near North Yakima, Wash., had to be lined with sheet iron to preserve it from wearing action of grit, and one of the large pipes on the King's Hill project in Idaho was nearly cut in two at one place by the circular movement of chips and débris floating on the surface near the intake where the pipe was not full.

With so many influences affecting the life of wood pipe no attempt should be made to strike an average of durability except in cases where attending conditions are known to be the same. Where pipes are fully exposed and supported free from all contact with the soil the conditions are much less variable than otherwise, and a life of at least 20 years may be quite reasonably expected for either fir or redwood if properly maintained. If placed in the ground or in contact with the soil, the life of wood pipe may, under very favorable conditions, be much greater than 20 years, otherwise it may be a great deal less. In contact with soil the durability is nearly always a matter of some uncertainty.

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January 27, 1915.

(PROFESSIONAL PAPER.)

WIREWORMS ATTACKING CEREAL AND FORAGE CROPS.

By J. A. Hyslop,
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INTRODUCTION.

Wireworms are the larvæ of several kinds of hard-shelled beetles belonging to the family Elateridæ. The beetles are known colloquially as "click-beetles," "skip-jacks," snapping beetles, etc.[1] These names are all derived from the beetles' unique habit of snapping the forepart of the body when placed upon their backs or held between the fingers. This habit is undoubtedly of use to the beetles in righting themselves when accidently overturned, and may also be a means of escape from their predatory natural enemies.

Wireworms are elongate, more or less cylindrical, having a very highly chitinized cuticle, and measuring, according to the species, from one-half inch to over 3 inches in length. They have three pairs of short legs near the anterior end of the body. The color is usually yellow or reddish-brown. The cotton and corn wireworm is an exception to this description.

The false wireworms (fig. 1, *a*) will also answer to the above description, but can easily be distinguished by their ability to move very rapidly and by the clavate last joint of the antennæ; the true wireworms, though able to move rapidly in the soil, are not very agile when placed on the surface of the ground, and their antennæ never have clavate terminal joints. The term "wireworm" is also, though erroneously, applied to these false wireworms, which are, however, the larvæ of another group of beetles, the darkling beetles (Tenebrionidæ). These beetles can not snap the forepart of the body. One species of darkling beetle (*Tenebrio molitor* L., fig. 1, *b*) is common throughout the United States, and its larva, the meal-

[1] The Cherokee Indians recognize the large-eyed elater (*Alaus* sp.) by the name "tulskuwa," which means "one that snaps with his head." This interesting note was made by Dr. J. W. Fewkes and communicated to the writer by Mr. F. M. Webster.

worm, is found in granaries and warehouses, where it feeds upon stored products. Another genus (Eleodes) is found only in the territory west of the Mississippi River, and attacks cereal crops in the field. The name "wireworm" is also incorrectly applied to several species of millipedes (*Julus* spp., fig. 1, *c*).

The true wireworms, from an economic standpoint, are among the five worst pests to Indian corn and among the twelve worst pests to wheat and oats. They are also important pests to many other crops. Since 1841, when Dr. Thaddeus Harris first published an account of these insects,[1] the literature of economic entomology has been replete with references to their depredations, and from the standpoint of the entomologist, as to the difficulty of combating them, they probably rank second only to the white grubs (*Lachnosterna* spp.).

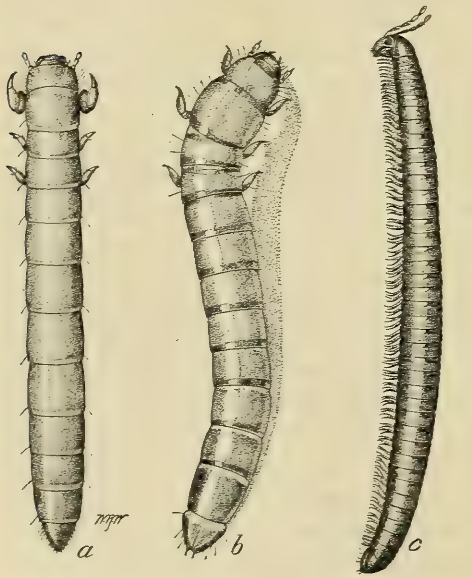

FIG. 1.—Larvæ likely to be mistaken for wireworms: *a*, False wireworm; *b*, mealworm; *c*, *Julus* sp. All enlarged. (Original.)

In view of the recently enacted Federal quarantine bill these insects assume an added interest, inasmuch as they can easily be introduced in the larval condition within fleshy roots, bulbs, and tubers. Mr. E. R. Sasscer, of the Federal Horticultural Board, recently intercepted an elaterid larva in the root of *Aralia cordata* from Japan; the larva was in good condition and is still alive in our laboratory (October, 1914). The writer has often seen the larvæ of *Agriotes mancus* Say within potato tubers that had been in a root cellar all winter.

These insects are destructive to cereal and forage crops in the larval stage only, although the adults of certain species (*Limonius discoideus* Lec., etc.) do considerable damage to the blossoms of fruit trees in the Pacific Northwest, and Fletcher reports[2] similar depredations of the adults of two other species (*Corymbites caricinus* Germ. and *C. tarsalis* Melsh.). The forms attacking cereal and

[1] Harris, T. W. Report on the Insects of Massachusetts Injurious to Vegetation, p. 46–50. Cambridge, 1841.

[2] Fletcher, James. Report of the Entomologist and Botanist, Central Experiment Farm, Canada, for 1892, p. 4. Ottawa, 1892.

forage crops confine their attention to the seed, roots, and underground stems and are exclusively subterranean, with the single exception recorded by Mr. E. O. G. Kelly, of this office, wherein he mentions finding a species (*Monocrepidius vespertinus* Fab.) damaging wheat at Wellington, Kans., by boring in the hollow of the wheat stems and not among the roots.

Their depredations are first to be noticed, with the exception of the cotton and corn wireworm, immediately after seeding, when they attack the seed, eating out the inside and leaving only the hull. When they are very numerous they often consume all the seed, making reseeding necessary, and in severe outbreaks a second reseeding is sometimes made before a stand is obtained. Aside from the extra labor and cost of the seed, this delays the planting of the crop, and if it be corn, in the Northern States the season is too short to mature so late-planted a crop and, except for the fodder, it is a failure. Where wireworms are present, even in very small numbers, corn will make a poor stand, which will necessitate the planting-in of missing hills. In some regions where these insects are quite numerous it is customary to sow three or four times the amount of seed that would normally be necessary in order to get a good stand.

KINDS OF WIREWORMS.

Several hundred species of Elateridæ occur in North America. They vary enormously in their habits, some forms living in dead and rotten wood (Alaus, Elater, Adelocera, etc.). Alaus has also been recorded as boring in solid wood, though the writer is inclined to discredit this observation, and other species live under moss (Sericosomus). A number of species abound in heavy moist soil filled with humus (Melanotus, Agriotes, etc.), while some prefer well-drained soils (Corymbites), and still others (Horistonotus) are most destructive on high sandy land which is very poor in humus. Many wireworms have been recorded as predaceous (Alaus, Hemirhipus, Adelocera, etc.).[a] I am told by Mr. T. H. Jones, recently associated with the Rio Piedras Sugar Planters' Experiment Station, that the large luminous elaterid (*Pyrophorus luminosus* Illiger) of the West Indies is a decidedly beneficial insect, as it feeds on the Lachnosterna larvæ in the sugar-cane fields. Through the kindness of Mr. G. N. Wolcott and Mr. R. H. Van Zwalenburg I now have (October, 1914) a Pyrophorus larva from Cuba, one from Jamaica, and several from Mayaguez, P. R. All of these larvæ are living and apparently thriving on the larvæ of our native Lachnosternas.[b] That this insect may some day be introduced into the southern United States as a natural enemy of Lachnosterna is not at all improbable. At least one instance

has been noted[1] in which a wireworm [*Lacon* (*Agrypnus*) *murinus* L.] lived in the stomach of a child. Most of our common species lay their eggs on sod or very weedy land, but the wireworms (*Corymbites* spp.) of the dry-farming country of the Pacific Northwest are severe pests on land that has been seeded to wheat, by the summer fallow method, for the past 15 years, and, as this land was originally sage-brush prairie, it probably never was in sod.

Several distinct kinds of true wireworms are destructive to cereal and forage crops in the United States; and since, as has already been stated, the different kinds vary more or less in their life histories, there is consequently a variation in the method of control as recommended in the following pages of this bulletin. It is therefore quite necessary to determine the identity of the wireworm, and to meet this necessity the many species of importance as pests to cereal and forage crops are treated separately.

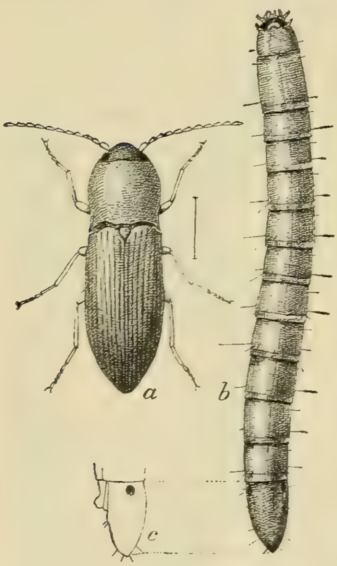

FIG. 2.—The wheat wireworm (*Agriotes mancus*): *a*, Adult beetle; *b*, larva; *c*, side view of last segment of larva. All enlarged. (From Chittenden.)

THE WHEAT WIREWORM.

(*Agriotes mancus* (Say), fig. 2.)

The adult of the wheat wireworm is a small brown beetle a little over one-fourth of an inch in length, quite robust, and moderately covered with very short, fine hair. The larva is pale yellow in color, very evenly cylindrical, and very highly polished. When full grown the larva measures about an inch in length and is about as thick as the lead in a lead pencil. These wireworms will be readily recognized by the singly pointed ninth abdominal segment and the two black spots on the upper side of this segment near its base.

This is one of the most common wireworms of the northeastern and middle western United States. A report of this species as a pest in the dry-farming regions of Washington State[2] is undoubtedly a

[1] Sandberg, G. El tilfälde af Coleopterlarvers tilhold i tarmkanalen hos et Menneske. In Entomologisk Tidskrift, v. 11, p. 77–80, 1890.

[2] Scobey, J. O'B. Wireworms. Washington Experiment Station. (State Agricultural College and School of Science.) Bulletin 4, p. 75–80, 3 figs., May, 1892.

misidentification, the insect probably being *Corymbites* sp. The wheat wireworm is normally a grass feeder, living on the roots of sod, and with the abundance of its natural food supply producing no appreciable disturbance in the meadows, but when the sod land is broken these wireworms concentrate in the drill rows or hills of corn, the usual crop to follow sod in the eastern United States, and often cause absolute failure of the crop by destroying the seed and eating off the roots of such plants as may germinate. This species is usually more destructive, therefore, on land recently broken from sod. Last year (1913) the writer investigated an outbreak in northern New York and located as many as 10 wireworms to the hill in cornfields, rendering the crop, so far as grain was concerned, an absolute failure. This year (1914) the same field was again planted in corn, and again the wireworms destroyed most of the crop.

The larvæ spend three years in the soil before transforming to beetles, so that the depredations of this pest may be looked for during the second season as well as the first following the breaking of sod.

LIFE HISTORY.

The beetles are in evidence early in the spring, and at this time can be swept from wheat and, in fact, from any vegetation around the fields, or they may be found under boards and rubbish. Mating occurs during April and May, and immediately egg-laying begins. The eggs are deposited in grasslands exclusively, so far as our observations go, the female burrowing into the ground or under rubbish to oviposit. The young larvæ feed during the ensuing summer, and, hibernating when about half grown, resume feeding the following spring. They continue to feed during the second summer and hibernate the second winter as full grown or mature larvæ. The third spring they resume feeding and continue it until early in July, when they leave the plants and form small earthen pupal cells in the soil.

In 1913 Agriotes started to pupate about July 15 in northern New York. The writer found many mature larvæ and pupæ in the fields at Bridgeport, N. Y., on the shore of Lake Oneida, on July 17, while investigating a severe outbreak of this pest on the farm of Mr. C. J. Fisher. Other larvæ collected at Bridgeport pupated as late as August 12. In 1914 several hundred larvæ were reared in the Hagerstown laboratory. All that became adult this year pupated between the middle and the end of July. The pupal stage varied in duration from 15 to 21 days.

Specimens collected by Mr. J. J. Davis, of this bureau, at Watertown, Wis., pupated on August 8. Mr. Pettit found the pupæ in

the rearing cages on August 26 and adults emerged as late as the middle of September at Grimsby, Ontario, Canada.[1]

The pupal stage usually lasts from 15 to 19 days. One specimen collected at Watertown, Wis., by Mr. Davis pupated on August 8 and the adult emerged August 19. A specimen collected at Bridgeport, N. Y., pupated on August 12 and emerged September 1. Other specimens collected July 25 at the latter place became adult August 12.

The pupal chamber consists of an oval cell, the long axis of which is perpendicular, located at a uniform depth of about 5 inches below the surface of the soil. The dust mulch in the case under discussion was 4 inches deep and the pupal cells were about 1 inch deeper than cultivation in the moist, firm soil. The pupa stands erect in the cell with the head upward, the larval exuvium being at the bottom of the cell.

The adult evidently passes the remainder of the summer in the pupal cell, in which it also later hibernates. Matured adults were found in these cells in the fields at Bridgeport, N. Y., as late as September 15, and in our rearing cages adults passed the winter without feeding or drinking.

Three distinct generations of larvæ were collected in the field in the summer of 1913—full-grown larvæ about to pupate, half-grown larvæ, and larvæ about one-fourth inch long—actively feeding on the corn. We have now in the laboratory, subject to outdoor temperature, two distinct generations of larvæ collected in the summer of 1913. The first generation—that is, the largest larvæ collected—all transformed to adults during August. Mr. Pettit and several others have made similar observations, and there is no doubt that this species, at least in the northeastern United States, spends three years as a larva.

FOOD PLANTS.

Agriotes mancus was observed at Bridgeport, N. Y., feeding upon corn seed and roots, potato tubers, wheat roots, carrots, and the underground stems of string beans; a single specimen was also found within the stem of the common field mushroom (*Agaricus campestris*). Other writers have found it attacking the cucumber, turnip, and cabbage. Mr. Theo. Pergande, of this bureau, records[2] a larva of this species feeding on the larva of a lamellicorn beetle in one of his rearing cages. The writer is of the opinion, however, that normally this species is not predaceous.

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[1] Pettit, J. Description of the wheat wireworm (*Agriotes mancus* Say). *In* Canad. Ent., v. 4, No. 1, p. 3–6, fig. 1, January, 1872.

[2] U. S. Dept. Agr., Div. Ent., Notes, v. 4, No. 2795, Oct. 5, 1882.

REMEDIAL MEASURES.

We recommend plowing sod land immediately after the first hay cutting, usually early in July, when the land is intended for corn the following year. This land should be cultivated deeply throughout the remainder of the summer. Land that is in corn and badly infested should be deeply cultivated even at the risk of slightly "root-pruning" the corn. This cultivation should be continued as long as the corn can be cultivated, and as soon as the crop is removed the field should be very thoroughly cultivated before sowing to wheat. In regions where wheat is seeded down for hay any treatment of infested wheat fields is precluded. Where wheat is not followed by seeding, the field should be ploughed as soon as the wheat is harvested.

Thorough preparation of the corn seed bed and a liberal use of barnyard manure or other fertilizer will often give a fair stand of corn in spite of the wireworms, a vigorous plant often being able to produce roots enough to withstand the depredations of several wireworms.

Though we realize that usually this is not practicable, the interposing of a crop not severely attacked by wireworms, such as field peas and buckwheat, between sod and corn would materially reduce the number of wireworms in the soil when the corn was planted.

THE CORN AND COTTON WIREWORM.

(*Horistonotus uhlerii* Horn, fig. 3.)

The adults of the corn and cotton wireworm are small, slender, and dusky brown; the largest is a trifle over three-sixteenths of an inch in length and can easily be distinguished from other forms infesting cereal crops by the heart-shaped scutellum. The wireworms of this tribe (Cardiophorini) are very unlike any of the other wireworms. They are not hard and wiry, but soft, membranous, and elongate. The body, which is usually white, appears to be composed of 26 segments, every third segment being swollen. The last segment is simply pointed. The head, which is yellow, is long and slender, with a pair of very prominent dark-brown jaws. When full grown these wireworms measure about an inch in length and are but little thicker than pack thread.

Unlike most of the eastern wireworms, which are usually most destructive in damp, low-lying fields, these insects seem to be far more numerous on the higher parts of the fields in light sandy soil.

These wireworms are among the most troublesome species of the southern United States. Mr. W. A. Thomas records[1] one species of

[1] Thomas, W. A. Corn and Cotton Wireworm (*Horistonotus curiatus* Say). So. Car. Agr. Exp. Sta., Bul. 155, 10 p., figs. [i. e., pls.] 6, March, 1911. I have since been informed by Mr Conradi that this is a misidentification and that the species in question is *H. uhlerii.*

this genus (*Horistonotus curiatus* Say) as one of the worst pests in South Carolina.

Mr. Vernon King, of this office, is at present investigating a very serious outbreak of *Horistonotus uhlerii* in Missouri and has prepared the following preliminary account of this species:

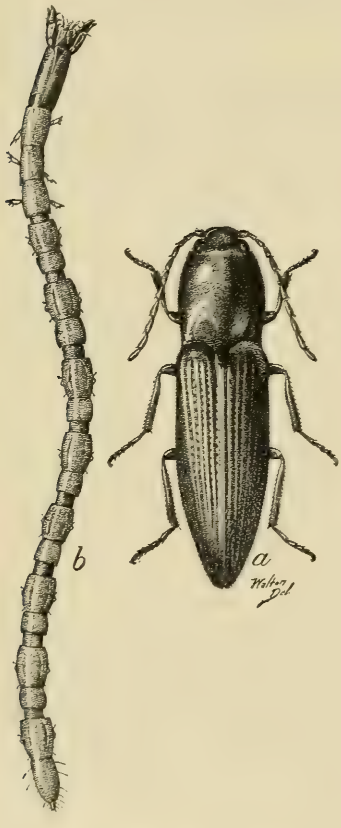

FIG. 3.—The corn and cotton wireworm (*Horistonotus uhlerii*): *a*, Adult beetle; *b*, larva. Enlarged. (Original.)

Horistonotus uhlerii Horn is a serious pest to corn in southeastern Missouri, and to corn, cotton, and cowpeas in northeastern Arkansas, and has been reported from the Carolinas and Illinois.

The larvæ may be found about the roots of their host plants in large numbers, nearly 50 having been taken from one hill of corn. Adults, pupæ, and larvæ can be seen in June, all beneath the surface of the soil, and later the adults will be found above the ground, resting on the plants. The eggs are probably laid about the end of June in the soil, on or about the roots of corn and cowpeas, for minute larvæ have been taken early in July. In May and June the larvæ are most plentiful, but as the season advances they become scarce, and finally disappear by the time winter sets in. By the third week in August the adults can no longer be found. Under laboratory conditions the larvæ pass the winter partly grown, and no doubt in nature they hibernate in the same form, but in what location is not yet known.

Although corn, cowpeas, and cotton are the main hosts of this insect, the larvæ feed on the roots of Johnson grass (*Sorghum halepense*) and have been reported as feeding on crab grass.

Infested corn plants become wilted and stunted, with leaves of a bluish shade, and brown at the tips, standing out from the stalk stiffly instead of bending over gracefully as in a healthy plant. Deprived of most of the roots through the work of the larvæ, the plant can be pulled up with little effort. Weak individuals soon succumb, leaving gaps in the rows, but the more vigorous plants put forth new roots in abnormal numbers. These are matted together and distorted, and although the plants survive, only nubbins are produced. Tall and apparently healthy plants may have larvæ among the roots without damaging the corn materially. The infestation, therefore, is not confined to the impoverished areas.

In cowpeas the fibrous roots suffer most, the thicker roots being perforated, so that the plants become yellow and dwarfed and fail to vine.

Cotton is injured in the early stages by the larvæ boring into the seed and injuring the very young plants, checking the growth so much that the plant dies or struggles along only to produce little or no cotton.

Rolling land infested by this insect presents a patchy appearance, the sandy knolls standing out distinct and bare, being overgrown later with weeds, particularly crab grass, briers, and morning-glory.

The infestation seems to be worst after a crop of cowpeas, but the exact significance of this crop in relation to wireworm injury has yet to be determined. Applications of barnyard manure and of wood ashes have had no effect in checking this pest. On account of the susceptibility of the larvæ and pupæ to exposure, plowing the soil in the heat of the sun would undoubtedly destroy many of the wireworms. The objection to this method, however, would be that the planter is occupied with other farm operations at that time, and also there would be difficulty in getting at these areas, which are often scattered, irregular, and isolated. From the data thus far gathered we can not say what effect fall plowing would have on this insect. Further investigation, however, will in all probability give a clue to remedial measures.

WIREWORMS OF THE GENUS CORYMBITES.

In the literature of American economic entomology there is no reference to beetles of the genus Corymbites as pests to cereal and forage crops. In the Pacific Northwest two species (*C. inflatus* Say and *C. noxious* Hyslop) are among the worst pests to cereal crops. The habits of the two species are quite distinct and will be treated separately. The occurrence of *Corymbites cylindriformis* Hbst. in enormous numbers in alfalfa and wheat fields about Hagerstown, Md., this spring (1914), and the finding of Corymbites larvæ in these fields at various times, might indicate that the genus is represented among the cereal and forage pests in this region also.

In Europe the habits of several species of this genus have been recorded by Schiodte and Perris. *C. pectinicornis* L., *C. castaneus* L., and *C. sjlandicus* Müll. are found living in woody meadows and *C. æneus* Fal. is found in fields.[1]

C. latus Fab. is recorded [2] as living "in the ground like other insect larvæ, feeding on roots * * *. They cause great damage to carnations in flower gardens." Following is a note by Mr. Pergande from the Bureau of Entomology files:[3] "Elaterid larva in apple tree, received from B. C. Hawkins, Horse Cove, Macon County, N. C. A larva of an elaterid found in a boring in trunk of apple with a dead larva of *Saperda bivittata*."

This note, though the correctness of the determination of the wireworm is not certain, is interesting, inasmuch as it seems to indicate that some species of Elateridæ now classified as Corymbites are

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1 Schiodte, J. C. De metamorphosi eleutheratorum observationes, pt. 5, p. 520–522, pl. 8, fig. 9–10, pl. 10, fig. 4, 1871.

2 Perris, Édouard. Larves des Coléoptères, p. 179. Paris, 1877. "Cette larve vit dans la terree soit d'autres larves ou insectes, soit de racines. M. de Bonvouloir, en m'en envoyant des echantillons, me l'a signalée comme causant de grands degâts aux œillets de son parterre."

3 U. S. Dept. Agr., Div. Ent., Notes, v. 8, No. 6187, Apr. 3, 1894.

predaceous, while other forms also in this genus are known to be exclusively vegetable feeders.

During the spring of 1909 a reconnoissance was made to determine the extent and nature of the damage being done by these insects. Circular letters with blank forms inclosed were sent to the agents of the warehouse and elevator companies at most of the large grain-shipping points in the Pacific Northwest. These men are very intimately in touch with the farmers and usually know of any serious depredations that are likely to affect the production of grain. From their replies we found that corn was being seriously damaged at Spokane, Pullman, Kiona, Johnson, and Colville, in Washington, and Latah and Mineral in Idaho; oats were being almost completely destroyed at Ritzville, Downs, Espanola, Govan, and Vancouver, in Washington, and Moscow and Latah in Idaho; and that wheat was being damaged at Wilbur, Connell, and Govan in Washington. The fact that damage to wheat was not reported from more localities does not signify that wheat is less susceptible to the attacks of these insects. The buyers will not report any damage to wheat for fear of starting a scare among the farmers and thereby abnormally raising the price asked when the buying opens in the fall.

THE INFLATED WIREWORM.

(*Corymbites inflatus* Say.)

The inflated wireworm occurs throughout most of the northern United States, but is limited as a pest to cereal crops, so far as our observations now record, to the regions of eastern Washington and Oregon and western Idaho, known as the semiarid Transition Zone and characterized, when not under cultivation, by the presence of bunch grass (*Agropyron spicatum*) and June grass (*Poa sandbergii*) and by the absence of sagebrush. This region is only partly summer fallowed, crops often being grown on the same land for several consecutive years.

The beetle is robust, but little more than one-fourth of an inch in length, and of a slate-gray color, sometimes being almost black. The wireworm is about one-half inch long, depressed, with a pair of backwardly directed spurs on the ninth abdominal segment, and pale yellow.

In the spring of 1909 Mr. George I. Reeves, of this bureau, recorded finding the larvæ of the inflated wireworm damaging seed corn at Pullman, Wash. His observations were carried on principally in the cornfield of a Mr. Curtis, north of the town. On this farm he found from 4 to 10 larvæ to the hill when he first investigated the outbreak, on May 24, 1909. The wireworms were in various stages of

development and were feeding on the seed, which had been planted on May 10 and 17, eating out the kernels and leaving only empty hulls. Usually the roots of such plants as had escaped were not damaged. The particular field under observation had been in oats in 1908 and in wheat in 1907. On June 1 Mr. Reeves again examined this field and then found the stand very poor, and the wireworms seemed to be more numerous than when he first examined it, as from 18 to 20 were to be found in nearly every hill. At this point the investigations were turned over to the writer.

On June 20 the entire field was harrowed and reseeded, the first seeding being absolutely destroyed by these wireworms. The second seeding started very well and looked as though it would succeed. Many wireworms were still present, however, and by July 8 the second seeding was about half destroyed and had to be planted in by hand. The season was then so well advanced that the crop was practically a failure.

LIFE HISTORY.

Early in May the beetles emerge from the pupal cells in which they pass the winter, a number of beetles having been caught at Pullman, Wash., by Mr. Reeves as early as May 5, 1908. They are about in enormous numbers during late May and early June. On May 28, 1910, the writer collected over a hundred of these beetles in a few minutes from some rosebushes in a fence row along the side of a last year's wheat field. The beetles continue abundant until early July, and by the middle of this month they have all disappeared but a few stragglers. During June the beetles mate and lay their eggs. The larvæ feed during this summer and pass their first winter about half grown. They resume feeding the following spring and continue to feed during the second summer, passing the second winter as nearly mature larvæ. The larval life is completed early the third spring, when they transform to pupæ during late June and early July. The last transformation takes place in late July and early August, and the adult beetles remain in the pupal cells from that time until early the fourth spring. Thus the wireworm, as such, is in the ground during the growing season of three years.

FOOD PLANTS.

The beetles of this species were observed in large numbers during May, 1910, at Pullman, Wash., on wild rosebushes, where they were apparently eating the petals of the unopened rosebuds, as many as 10 beetles having been counted on a single bud and the buds being

badly riddled with holes. In a rearing cage the beetles were observed eating into kernels of wheat which were exposed on the surface of the ground. The beetles are also to be collected in large numbers in clover fields. The larvæ, so far as our records show, attack corn, wheat, and potatoes. They also undoubtedly attack oats and barley.

THE DRY-LAND WIREWORM.

(*Corymbites noxius* Hyslop,[1] fig. 4.)

The dry-land wireworm, so far as we at present know, is confined to the Upper Sonoran Zone of Washington State, though it will undoubtedly be found in the Upper Sonoran of Oregon. This zone is

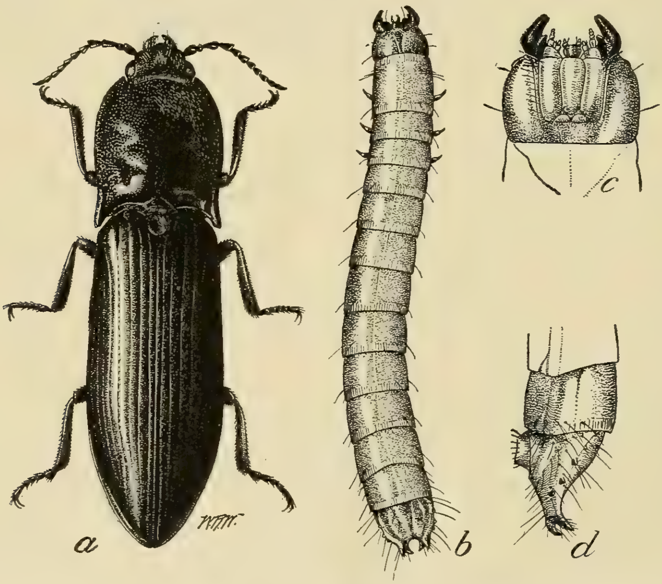

FIG. 4.—The dry-land wireworm (*Corymbites noxius*): *a*, Adult; *b*, larva; *c*, under surface of head of larva; *d*, side of last segment of larva. *a*, *b*, enlarged; *c*, *d*, more enlarged. (Original.)

characterized by the presence of sagebrush and occupies that part of Washington lying south of the Columbia River, east of the Cascade Mountains, and west of the semiarid Transition Zone, extending up the Snake River into Idaho and across the Columbia River into Oregon. This region is almost exclusively dry-farming country, summer fallowing being necessary to obtain enough moisture to mature wheat and other cereals.

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[1] Hyslop, J. A. Description of a new species of Corymbites from the Sonoran Zone of Washington State (Coleoptera, Elateridæ). *In* Proc. Biol. Soc. Wash., v. 27, p. 69–70, Mar. 20, 1914.

The beetle of this species is about one-half inch long, quite slender, and jet black in color. The wireworm is very similar to the inflated wireworm.

Early in April, 1910, our attention was called to a series of severe wireworm outbreaks in the region above outlined. On the 5th of the month the farm of a Mr. Dunnigan, at Connell, Wash., was visited. He was at that time reseeding 1,800 acres of wheat which had been killed out by these wireworms. From Connell we proceeded to Govan, Wash., and here we found the wireworms also doing considerable damage. In a fallow field that had been ruined by wireworms when in oats in 1909 we found them in enormous numbers. These wireworms when in the field are usually to be found between the dust mulch and the moister earth below. This species is more or less destructive throughout its range. During 1910 reports of severe outbreaks were received from eight wheat-receiving stations in the States of Washington and Idaho.

LIFE HISTORY.

This beetle is about during June and July, at which time it deposits its eggs in wheat fields, weedy fallow fields, and volunteer wheat on fallow land. The eggs are undoubtedly laid underground by the female burrowing into the soft earth, as many adults were collected in the fields at a depth of from 5 to 8 inches below the surface which were not in pupal cells. Mr. J. E. Graf, of the Bureau of Entomology, has found this to be the case with the sugar-beet wireworm.[2] The young larvæ are to be found in the soil during August and the remainder of the summer, but their depredations are not noticeable at this time, as, in the region where the species occurs, wheat is the only extensively grown crop. The young wireworms pass their first winter in the soil at a depth of from 12 to 20 inches below the surface. The following spring and summer they spend in the summer fallow and are not noticed. Their second winter they again hibernate as wireworms, and in the spring of their third year, the field being now planted to wheat, they turn their attention to the seed and young plants, and it is at this time that their depredations are so startlingly noticeable. They feed during late March, April, and May, and early in June burrow to from 4 to 8 inches below the surface, making small oval cells, in which the very fat larvæ lie in an inactive condition during June, July, and early August, when they pupate and the adults emerge from the pupal skins the middle of that month, but remain in the pupal cells the remainder of that summer and the ensuing winter, not emerging from the ground until the fourth spring from that in which the eggs were laid.

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[2] Graf, John E. A Preliminary Report on the Sugar-Beet Wireworm. U. S. Dept. Agr., Bur. Ent., Bul. 123, p. 18, Feb. 28, 1914.

In the spring of 1910 a large number of these larvæ were collected in the wheat fields at Govan and Wilbur, in Washington State, and confined in a root cage made by sinking a molasses barrel to the level of the earth surface in a field at Govan and closing the top with a short cylinder of sheet iron covered with wire gauze. The barrel was filled with earth and wheat planted therein. The larvæ could easily be separated into three distinct groups, according to size, which indicated a 3 years' life cycle. Later observations on the material in the rearing cage proved this to be actually the case.

Two lots of larvæ were confined in this cage—one on April 14 and the other on April 30, 1910, so that all must have hatched from eggs laid in 1909 or previous to that year. On June 21 the cage was examined and a number of the larvæ were found to be at from 4 to 8 inches below the surface, resting quietly in oval cells. They were very fat at this time. The cage was not examined again until November 4, and at this time 3 adults, evidently of the 1907 generation, were found at about the same depth as the larvæ observed in June. They were still in the pupal cells, as was evident from the last larval skins and the pupal skins found with them. The following spring (1911) the cage was examined on March 29. Several larvæ were found at this time. They were now moving actively about in the soil and almost immediately attacked some seed wheat sown in the cage on this date. An adult still in the pupal cell was also found at this time. The cage was next examined on July 4, at which time an adult was found on the surface of the ground. Several full-grown larvæ were also found on this date in their cells at the usual depth of from 4 to 8 inches below the surface. These were evidently the larvæ hatched from eggs laid in 1908. On August 17 the cage was examined and at about 5 inches below the surface a pupa and an adult were found. The latter had evidently just transformed, as it had not yet become quite black and was still very soft. The following day the cage was entirely emptied and at between 18 and 20 inches below the surface 10 larvæ and an adult were found in soil that was very hard, and very slightly moistened, in fact merely moist enough to prevent its being absolutely dry. The larvæ seemed to be full grown and had evidently just completed a molt, as they were quite soft. These were evidently of the 1909 generation.

REMEDIAL MEASURES.

As will be seen from the life histories of these two species, the generations about to become adult are inactive larvæ from June to August and very delicate pupæ during the early part of the latter month. These resting larvæ and pupæ are usually at a depth of from 4 to 8 inches below the surface, and any disturb-

ance of the soil to that depth at this time would undoubtedly destroy them. At this time of the year the ground is very hot and the air exceedingly dry in this region, and even the resting larvæ and pupæ that were not actually crushed by the cultivation would soon succumb to drying when their cells were broken open. The writer had considerable trouble in bringing pupæ in from the field to his rearing cages and was forced to resort to tightly closed tin boxes which were fitted in the bottom with moistened blotters.

The usual farm practice in the region where the dry-land wireworm is troublesome may be roughly outlined as follows: Immediately after seeding the wheat in early spring the fallow land is plowed to a depth of from 4 to 7 inches. This is usually in April, but if horses and help can be spared from seeding, the summer fallow is plowed as early in the spring as the land can be worked. The next operation on the fallow land is disking it late in June or early in July to maintain the dust mulch and kill out the weeds and volunteer wheat. Many of the more progressive farmers now advocate, and a few practice, fall plowing of stubble and only disking the fallow land in the spring. The year following the summer fallowing the field is disk harrowed early in the spring if the land has run together during the winter and is caked; otherwise the land is harrowed with a drag or spike-tooth harrow. It is then seeded and dragged and receives no further treatment until harvest. The seeder is usually set to sow at a depth of about 3 inches, though if the moisture is high enough 1 inch is sufficient. Wheat hay is used extensively in this country and is cut while the wheat is in the dough, which is usually from July 4 to 15. The wheat crop is harvested from the 1st of August until the 1st of September.

We recommend altering this practice in order to destroy wireworms in the following manner:

(1) *Disk or drag harrow* the summer fallow as early as possible *in the spring*, in order to produce a dust mulch and thereby conserve the accumulated winter's moisture; (2) *continue disking* as often as is necessary to maintain the dust mulch and keep down the weeds; (3) *plow the summer fallow* in July or early in August, and immediately drag; (4) *plow the stubble* as soon as the crop is off.

As these worms are of three different ages in most infested fields, and as only about one-third of these will be in the pupal stage each year, it is evident that the first year of this practice will not show startling results. However, if the practice is continued for a couple of years it will undoubtedly reduce the number of these pests very considerably. Aside from its beneficial results in killing insects, this method of handling the land will materially reduce the weeds. The early disking merely softens up the soil and allows all the weed

seed present to sprout, and the entire crop of weeds is subsequently destroyed by the summer plowing. By the present method of farming the weed seeds are turned down to such a depth that many can not germinate, but lie dormant and sprout whenever they happen to be brought to the surface by subsequent cultivation. One crop of weed seed is in this manner often a pest for several succeeding years.

A slight variation of these suggestions will readily adapt them to the more humid sections inhabited by the inflated wireworm.

THE CORN WIREWORMS.

Several species of beetles belonging to the genus Melanotus are recorded as pests to cereal and forage crops in the United States. The beetles usually range from medium-sized to large forms measuring from one-half to three-fourths inch in length. They vary in color from light reddish-brown to almost black. The beetles of this genus can always be distinguished with a low-power lens by the comb-like claws on the last tarsal segment.

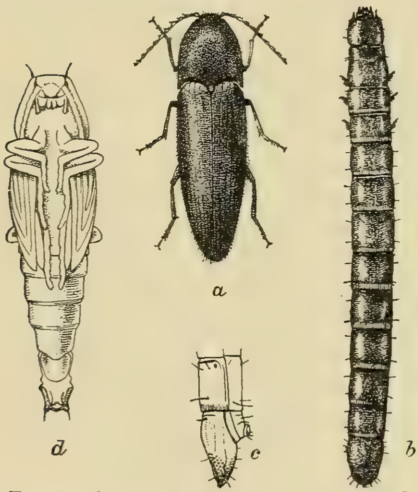

FIG. 5.—One of the corn wireworms (*Melanotus communis*): *a*, Adult; *b*, larva; *c*, last segments of same; *d*, pupa. All enlarged. (From Chittenden.)

The wireworms are reddish-brown in color, about $1\frac{1}{4}$ inches long, cylindrical in shape, and always with the last joint of the body ending in three inconspicuous lobes.

Many species of this genus inhabit decaying logs, and several writers record them as predaceous.[1] A note in the Bureau of Entomology files,[2] by Mr. Pergande, records a larva of this genus as feeding on the eggs of a locust, or grasshopper. A similar record,[3] dated September 19, 1884, is made by the same observer, wherein a Melanotus larva was found with locust eggs and reared to the adult condition by feeding on potato and dead beetle (lamellicorn) larvæ.

These wireworms are a pest to cereal and forage crops in the Middle Atlantic States, the New England States, and in the Mississippi Valley from Kansas northward. Forbes places *Melanotus communis*

[1] Perris, Édouard. Histoire des insectes du pin maritime. *In* Ann. Soc. Ent. France, ser. 3, T. 2, p. 139 (séances du 13. Avril, 1853).
[2] U. S. Dept. Agr., Div. Ent., Notes, v. 4, No. 2883, Oct. 9, 1882.
[3] U. S. Dept. Agr., Div. Ent., Notes, v. 4, No. 2884, Sept. 19, 1884.

Gyll. (fig. 5) and *M. fissilis* (Say) as among the important corn pests of Illinois. Webster found *M. communis* a very serious pest in Indiana and Ohio; Comstock and Slingerland consider *M. communis* one of the worst wireworms in New York State; and Swenk records serious depredations of *M. cribulosus* Lec., *M. communis*, and *M. fissilis* in Nebraska.

In 1907 Mr. E. O. G. Kelly found a species of Melanotus attacking corn in North Dakota. In 1910 Mr. W. W. Yothers, of this bureau, investigated a very severe outbreak of these wireworms at Corry, Pa. At the time he visited the fields as many as 7 to 15 larvæ were to be found in nearly every hill. This field had been broken from sod in 1908. In 1912 Mr. Kelly found the larvæ of *Melanotus communis* so numerous at Wellington, Kans., that they entirely destroyed his experimental corn plantings. He also found the larvæ of this species attacking kafir seed at Mulvane, Kans., in the spring of 1912. In places they had completely eaten out the seed for spaces of from 4 to 6 feet in the drill rows. In 1914 we received reports of damage by wireworms belonging to the genus Melanotus from seven localities in Indiana, seven in Wisconsin, six in Maryland, three in Michigan, three in Iowa, and one each in Alabama, Ohio, Virginia, Kentucky, North Dakota, Vermont, and West Virginia.

Several species occur on the west coast, and *M. communis* is reported as a pest to wheat in Garfield County, Wash.,[1] but the writer is inclined to believe that the pest in this case was either a false wireworm or a species of Corymbites.

Mr. Pergande records[2] this species as attacking lettuce roots, wheat, and potatoes.

LIFE HISTORY.

The adults of these wireworms are flying about in late April, May, and June, when they undoubtedly deposit their eggs in the grasslands. The larvæ spend two to five years in the soil. That any have so short a life-cycle period as two years is not at all certain. We have, however, in our outdoor insectary, larvæ received from Inman, Nebr., April 19, 1912, subject to very nearly natural conditions. These larvæ were well grown when received and were at least of the 1911 generation. At the date of this writing (October, 1914) they are larvæ. They have passed the summers of 1911, 1912, 1913, and 1914 in the soil, and if they pupate next summer (1915) the adults will, without doubt, remain in the pupal cells until the spring of 1916, making, in this case, five full years from egg to egg. These beetles pupate during July and early August.

[1] Scobey, J. O'B. Wireworms. Wash. Exp. Sta. (State Agr. Coll. and School of Sci.), Bull. 4, p. 75, May, 1892.

[2] U. S. Dept. Agr., Div. Ent., Notes, v. 4, No. 2884.

Mr. Webster found pupæ in the ground August 19, 1885, at La Fayette, Ind.

At the Hagerstown Laboratory over 100 larvæ of this genus are under observation. Those that emerged as adults this year pupated between the end of July and the middle of August. The pupal stage varied in duration from 12 to 22 days.

The adults do not leave the pupal cells, however, until the following spring. Mr. Webster found adults of *M. communis* in pupal cells on March 17, 1894, at Wooster, Ohio, and the writer found an adult in a wheat field at Hagerstown, Md., on November 22, 1912. This adult was in a cell with its pupal and last larval exuvia. The cell was 1 inch below the surface, in the drill row in which several consecutive plants had been killed.

REMEDIAL MEASURES.

The larvæ of the genus *Melanotus*, so far as our observations go, are confined to poorly drained and usually to heavy, sour soil. In making a survey of Birch Creek and Eel Creek bottoms in Clay County, Ind., we were informed by nearly all of the farmers that up to within the past four years wireworms caused very large annual losses to corn growers, while for the past three years this pest has been quite unknown to them. Coincident with the disappearance of the wireworms we find that the land was tile-drained on most of the farms. That the tile drainage of the land was actually responsible for the disappearance of the wireworms is more than we are prepared to say. However, the coincidence is very suggestive.

WIREWORMS OF MINOR IMPORTANCE.

The following species, though not serious pests to cereal and forage crops over extensive areas, are, during certain seasons, very destructive in restricted localities.

The wireworms belonging to the genus Limonius are among the most important of this group. In 1909 the writer received report of serious damage being done to corn and potatoes at Spokane, Wash. The outbreak was investigated and proved to be very severe, but at the time no larvæ were reared. This year (1914), through the kindness of Mr. William Tews, of Spokane, the writer received a large number of these wireworms with the report of another serious outbreak. From this material we succeeded in rearing adults which are Limonius (species undetermined). The confused wireworm (*Limonius confusus* Lec.) has made its appearance in Illinois[1] within the last few years, and although its principal damage was confined to potatoes, it was also destructive to corn. The beetle is

[1] Davis, J. J. Preliminary report on the more important insects of the truck gardens of Illinois. *In* Ill. Farmers' Inst. 16th Ann. Rpt., p. 216–263, 42 figs. Springfield, 1911. Wireworms. *Limonius confusus* Lec., p. 251, figs. 36–37.

about three-sixteenths of an inch long, reddish-brown in color, and moderately hairy. The wireworm is about three-fourths of an inch in length and is depressed, with a shallow emargination in the terminal segment; the color, as in the beetle, is reddish-brown.

The species is recorded as attacking corn, potatoes, tomatoes, onions, cabbage, radishes, turnips, horseradish, and spinach. It burrows into the underground parts of the plants, quite ruining them for market purposes, and in the case of corn, tomatoes, cabbage, and onions often kills the plant. This species does not seem to attack beans, peas, cucumbers, melons, rhubarb, lettuce, and peppers, and these crops might be of value in clearing a badly infested field prior to seeding it to grain.

The sugar-beet wireworm (*Limonius californicus* Mann.) is a very serious pest to alfalfa and corn over restricted areas in California.[1] Alfalfa is so badly infested in certain localities that it has to be plowed out and reseeded every three or four years. This species lays its eggs during late April. The eggs hatch during late May and the larvæ spend the remainder of that season and the whole of the two succeeding seasons in the ground. They pupate during July and August of their third summer, the adults remaining in the pupal cells until the spring of the fourth year. Alfalfa fields badly infested with this wireworm should be plowed out immediately after the first crop is harvested and harrowed several times before reseeding. Land intended for corn should be plowed in late July or August of the year preceding cropping. Land in corn should be deeply cultivated during August.

The abbreviated wireworm (*Cryptohypnus abbreviatus* (Say)) occurs over the entire northern part of the United States, being quite common in New England and New York, and is recorded from New Jersey by Smith.[2] In the upper Mississippi Valley this species is also a pest and specimens have been collected in Utah and Washington.

The beetles of this species are very small, being little over three-sixteenths inch in length and quite broad and flattened. The color is very dark brown to almost black and the forepart of the body is very shiny. An obscure yellowish spot ornaments each wing cover near the tip. The legs are also obscure reddish-yellow.

The wireworm is about one-half inch long, flattened, with a pair of backwardly directed prongs on the ninth abdominal segment, and is pale yellow in color.

Owing to the confusion of this wireworm with *Drasterius elegans* Fab., the literature relative to either of these insects is very unre-

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[1] Graf, John E. A Preliminary Report of the Sugar-Beet Wireworm. U. S. Dept. Agr., Bur. Ent., Bul. 123, 68 p., 9 figs., 23 pl., Feb. 28, 1914.

[2] Smith, J. B. Catalogue of the Insects Found in New Jersey, p. 159. Trenton, 1890.

liable. The best account of the species of which we are cognizant is that of Comstock and Slingerland.[1]

On March 13, 1912, Mr. J. J. Davis received a communication reporting a very bad outbreak of wireworms on corn at Watertown, Wis., in 1911. The fields attacked were low-lying peaty muck-lands that had been reclaimed by tile draining. The correspondent said that he "plowed up a strip of land early last spring and turned up these insects by the millions, so that some of the furrows looked real white." Larvæ were inclosed with this communication and proved to be of this beetle. In June, 1913, Mr. Davis visited this locality and collected a number of the larvæ and sent them to the writer alive. They were confined in rearing cages on June 6. August 5 a pupa was found, and on August 14 the adult emerged from the pupa. Another larva pupated on September 2 and the adult emerged on September 11. These two records limit the pupal stage to nine days.

For this species we recommend plowing sodland, intended for corn the succeeding year, *during late August.* Cultivate corn as late as possible, and plow small-grain stubble during August, if possible.

Another genus of importance in this group is Monocrepidius. The two species of this genus recorded as attacking cereal and forage crops in the United States are quite distinct. One (*Monocrepidius lividus* DeG.) is a large species over one-half inch in length, of a dull, even brown color. It is shaped very much like a Melanotus, but can easily be distinguished from that genus by the simple tarsal claws. The other species (*Monocrepidius vespertinus* Fab.) is a small elongate beetle, a little over one-fourth inch long. The body is prettily marked with yellow and dark brown. Both of these species are more or less southern in distribution, *M. lividus* DeG. being distributed over the entire southern part of the United States from Florida to Texas and northward to northern New Jersey, scattering specimens being collected as far north as Massachusetts, while *M. vespertinus* covers the same territory, but is more generally distributed northward.

A third species, *Monocrepidius bellus* Say, is a very small form, the beetle being hardly three-sixteenths of an inch long. This species is quite often taken in cornfields during the summer and under stones in pastures during the winter about Hagerstown, Md. Dr. F. H. Chittenden[2] records this species as having been reared from larvæ feeding on the roots of creeping bent (*Agrostis stolonifera*) on the department grounds at Washington.

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[1] Comstock, J. H., and Slingerland, M. V. Wireworms. Cornell Univ. Agr. Exp. Sta., Bul. 33, p. 270, Nov., 1891.

[2] U. S. Dept. Agr., Div. Ent., Notes, v. 10, No. 7472.

Monocrepidius auritus Hbst. is also quite common about Hagerstown, adults being often found hibernating with *Drasterius amabilis* Lec. under stones. Mr. C. M. Packard, of the Hagerstown laboratory, collected a pupa of this species in the insectary garden on August 11, 1913. The adult emerged from this pupa on August 16. This year (1914) Mr. J. J. Davis sent the writer a large number of larvæ of this species from Indiana. The last two species will probably eventually be found to attack crops.

The largest, and in the southwest the most important, species of this genus is *Monocrepidius lividus* DeG. In the bureau files is a note made by Mr. Pergande, dated June 6, 1881.[1] Larvæ were found in hills of recently seeded sorghum. No locality accompanies this note. On July 4 one of the larvæ transformed to a pupa, and on July 11 the adult issued, making the pupal period just a week.

Mr. Kelly collected an adult in a hay pile March 21, 1911, and also a larva of this species burrowing in a young corn plant at Wellington, Kans., on June 11, 1910. This larva pupated on September 8, but was not reared to an adult. He also collected an adult in an alfalfa field on May 10 of that year. Another larva, supposed to be this species, was collected June 12 and was kept alive in a rearing cage until November 25, indicating that the species hibernates in the larval state. The particular specimen, however, died during the winter.

During July, 1911, Mr. G. G. Ainslie found the adults of this species on the fresh silk on the corn ears down in the tip of the husk. He found them in the act of eating the corn silk and also the pollen.

The writer, while investigating an outbreak of the "curlew bug" (*Sphenophorus callosus* Oliv.) at Hartford, N. C., found several of these wireworms in a cornfield. These larvæ were collected on November 4, 1911, and by December of that year one of the larvæ had eaten all his comrades and had gone into hibernation in the rearing cage in the office at Washington. The data relative to the life history of this individual can not be relied upon as of value in determining the normal life history, as the office was subjected to great extremes of temperature that winter, often freezing at night and being over 80° F. by noon. However, this larva transformed to a pupa and emerged as an adult between May 21 and June 7, 1912. This beetle lived in the rearing cage without food until July 24 of that year. Mr. G. G. Ainslie collected a larva of this species on March 25, 1914, in sod land at Orlando, Fla.

Undoubtedly second in importance, and in parts of the South probably first, is the southern corn wireworm (*Monocrepidius vespertinus* (Fab.), fig. 6). Mr. Kelly has found the larvæ of this species

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[1] U. S. Dept. Agr., Div. Ent., Notes, v. 2, No. 857, June 6, 1881.

doing considerable damage to wheat at Wellington, Kans. These larvæ attack the wheat in a very unique manner for wireworms. They do not seem to attack the roots, but bore into the cavity of the wheat stem and feed on its inner wall. In some fields as many as one-eighth of 1 per cent of the wheat stems were infested. A large number of these larvæ were placed in a rearing cage on May 6, 1910, and on June 24 four adults were found in the cage. Mr. Kelly found the adult beetles of this species numerous on corn plants in the field from July 3 to August 23. Early in March, 1910, an adult of this species was found in a clump of grass (*Andropogon scoparius*). In 1911 Mr. Kelly succeeded in rearing an adult from a pupa collected among the roots of corn. This adult emerged on July 19. Mr. T. H. Parks, at that time with this office, found the beetles very numerous on young corn at Winfield, Kans., and Oklahoma City, Okla., in June, 1910, and Mr. R. A. Vickery, also of this office, found the beetles very numerous on corn at Brownsville, Tex., in June. Mr. Pergande records[1] the injury to these beetles to cotton at Wetumpka, Ala., and Dr. J. B. Smith found the larvæ injuring beans at Da Costa, N. J.[2] Mr. W. R. McConnell, of this office, found the larvæ of these beetles very numerous in alfalfa fields at Carlsbad, N. Mex.

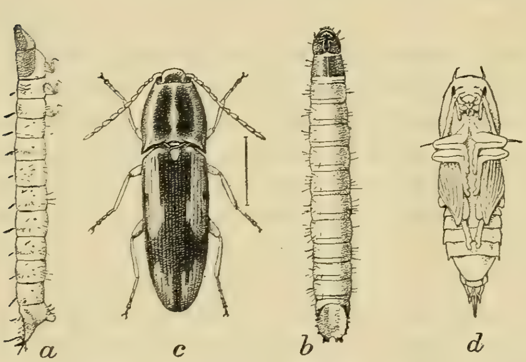

FIG. 6.—The southern corn wireworm (*Monocrepidius vespertinus*): *a*, Side view of larva; *b*, top view of larva; *c*, adult beetle; *d*, pupa. All enlarged. (After Chittenden.)

Owing to the superficial resemblance of the larva of Drasterius to those of Cryptohypnus, the notes in the files of the Bureau of Entomology relative to these two genera are very unreliable. Webster records[3] *Drasterius elegans* Fab. as a serious pest to corn and wheat in Indiana, and Forbes records finding larvæ attacking corn in Illinois.

Drasterius elegans is found throughout the northern half of the United States. *Drasterius amabilis* Lec. is common in the Middle Atlantic States and has also been collected in New England and the Mississippi Valley. All of the beetles in this genus are

[1] U. S. Dept. Agr., Div. Ent., Notes, v. 11, No. 8668, July 11, 1899.

[2] Smith, J. B. Annual Report of the New Jersey State Museum. Including a Report of the Insects of New Jersey, p. 285. Trenton, 1909.

[3] Webster, F. M. Report of observations upon insects affecting grains. *In* U. S. Dept. Agr., Div. Ent., Bul. (Old Ser.) 22, p. 52, 1890.

small, about one-fourth of an inch in length. They are yellow or reddish yellow in color, with more or less black marking. The wireworms are about one-half of an inch long when full grown. They are depressed forms with two prongs on the ninth abdominal segment and are yellowish colored, except the head and first joint, which are brownish.

In the general bureau note files, as well as those of the branch of Cereal and Forage Insect Investigations, are many notes referring to *Drasterius elegans* as predaceous, and also many other notes referring to this species as a pest to crops. None of these notes is at all conclusive, however, and in many cases it is very probable that the form attacking corn and wheat is really the abbreviated wireworm (*Cryptohypnus abbreviatus* (Say)), and it may be that the predaceous form is *Drasterius amabilis*, which the writer finds in many collections under the name *D. elegans*.

Mr. Theodore Pergande, of this bureau, received several larvæ of *Drasterius amabilis* from Manhattan, Kans., on May 3, 1877.[1] He says that these larvæ were found preying on the eggs of *Melanoplus spretus*. On June 20 some of them were killed and eaten by mites, so that nothing but the shell was left. June 25 the other larvæ were completely covered with small mites, so that they could scarcely move, and he believed that probably they would die, also.

These mites to which Mr. Pergande refers were evidently the hypopial stage of some tyroglyphid. In all probability the Drasterius larvæ ate one another, as this is a common occurrence when these larvæ are placed together in a rearing cage. He goes on to say:

> May 31, 1878, another larva of this species about half grown was placed with an Epicauta larva. It has eaten the Epicauta larva. June 18 pupated. July 9 issued.

This note gives a considerably longer pupal period than that observed by the writer at Hagerstown. In another note under the same number there is a record of the finding of a larva of this species within a potato stalk which was infested with *Trichobaris trinotata* Say, and it was probably feeding on these larvæ.

The writer found a very young *Drasterius amabilis* larva eating a pupa of *Meromyza americana* Fitch on July 9, 1912, at Hagerstown, Md. Mr. George Dimmock says that "this species (*D. amabilis*) devours locust eggs."[2]

Drasterius amabilis is very common in western Maryland, where the adults can be found under stones or rubbish from the middle of September until early in the spring.

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[1] U. S. Dept. Agr., Div. Ent., Mem. XII, Note 762P, May 3–June 25, 1877.

[2] Standard Natural History, edited by J. S. Kingsley, v. 2, p. 361. Boston, 1884. "* * * a few of these larvæ are carnivorous, the larvæ of *Drasterius amabilis*, in the United States, being known to devour locusts' eggs."

A larva was collected at the roots of a corn plant, which, however, it did not seem to be damaging, at Hagerstown, Md., in June. This larva pupated on July 6, and the adult emerged July 15. The beetle remained alive without feeding until September 12 of that year. On April 30 a large number of beetles were placed in a small root cage in which corn had been planted. On May 6 all the adults were removed. On July 31 the cage was examined and three full-grown larvæ and one pupa were found. This cage was again examined September 8, and two adults, which, judging from the color and hardness of the integument, were at least a week old, were found.

Pupæ collected in the field emerged July 28, and two larvæ collected July 8 pupated August 10, and one of the beetles emerged August 21, the other August 23.

From the foregoing data it is evident that the life cycle is completed within one season, a very exceptional condition in this group of beetles. The beetles leave their hibernating quarters in early spring and deposit their eggs early in May. The wireworms feed during May and June, and sometimes even throughout July. They start to pupate in early July, continuing pupation throughout July and early August. The pupal stage lasts from 8 to 13 days. The adults emerge from the ground in late summer and in the fall seek hibernating quarters under stones, boards, and rubbish.

Forbes records[1] a species of wireworm (*Asaphes decoloratus* (Say)) as attacking clover in Illinois. This species is also recorded[2] as a pest in New York State.

Mr. Kelly is now investigating an outbreak of a wireworm (*Lacon rectangularis* (Say)) in Kansas. This species has not heretofore been recorded as a wheat pest, but in a recent letter to the writer Mr. Kelly says:

> In one wheat field at Argonis, Kans., in the spring of 1912, as many as 27 per cent of the plants had been bored into and ruined in some spots, with an average of about 18 per cent for the field. Later, however, the damage was much greater, and it was a question whether the grain was worth cutting.

The collared wireworm (*Cebrio bicolor* Fab., fig. 7) has not as yet been recorded as an actual pest to any crops, but as several notes wherein this species has been recorded as feeding on cultivated plants have come to the notice of the writer, and as one of these plants is a cereal, we believe it pertinent to make a short note of this species, that it may be readily recognized should it ever become a serious pest.

The beetles of this species are not now considered as belonging to the same family as the true wireworms, but they are so intimately

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[1] Forbes, S. A. Insect Injuries to the Seed and Root of Indian Corn. Ill. Agr. Exp. Sta., Bul. 44, p. 226, May, 1896.

[2] Comstock, J. H., and Slingerland, M. V. Wireworms. N. Y. Cornell Agr. Exp. Sta., Bul. 33, p. 258–262, Nov., 1891.

related to these insects and the larvæ are so very wireworm-like that they can be treated, from an economic standpoint, as wireworms. The beetle is about three-fourths of an inch long, rather slender, with very prominent scythe-like jaws; the color is brown. The wireworm is cylindrical. The first joint of the body is very large and extends forward under the head, so that the head is partly inserted within it; the last joint is long and thimble-shaped. The wireworm when full grown measures 1¾ inches in length and is nearly an eighth of an inch thick. The color is reddish brown.

The genus is recorded by Schiodte[1] as living in moist earth in Europe. In the bureau files is a note[2] by C. V. Riley which records the finding of a pupa at the roots of a grapevine in July, 1874. No locality accompanies the note, which is with other notes made at St. Louis, Mo. On July 11 an adult emerged. In the same files another note[3] records this wireworm as injuring peach and other deciduous tree roots near Fairmont, Cal. In April, 1911, Mr. G. G. Ainslie sent a larva of this species to the writer, stating that he found it feeding on oat plants near Jackson, Miss. He sent two other larvæ of this insect to the writer from Orlando, Fla., where they were found in black, sandy soil.

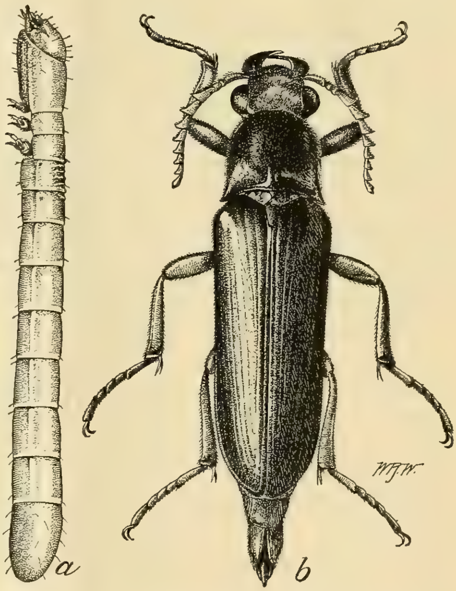

FIG. 7.—The collared wireworm (*Cebrio bicolor*): *a*, Larva; *b*, beetle. Enlarged. (Original.

Another interesting record of a wireworm (*Ludius hepaticus* Germ.) of decidedly minor importance is found in the bureau files.[4] Four larvæ of this species were found attacking cruciferous plants at Georgiana, Fla. Our only other record of this genus is one in which adults were actually reared from larvæ of *Ludius attenuatus* (Say) found in rotten wood; these larvæ were predaceous.

NATURAL ENEMIES.

Probably the most important factor in keeping wireworms in check are the birds. The following list of birds known, by examina-

[1] Schiödte, J. C. De metamorphosi eleutheratorum observationes, pt. 5, p. 530, 1871.
[2] U. S. Dept. Agr., Div. Ent., Mem. VII, No. 350X, July 11, 1874.
[3] U. S. Dept. Agr., Div. Ent., Notes, v. 5, No. 3681, June 24, 1885.
[4] U. S. Dept. Agr., Div. Ent., Notes, v. 4, No. 3570, Feb. 23, 1882.

tion of the crops and stomachs, to feed on Elateridæ, either as larvæ or as adult beetles, is compiled from the records of the Biological Survey of the United States Department of Agriculture:

Franklin gull (*Larus franklini*).
Herring gull (*L. argentatus*).
American black tern (*Hydrochelidon n. surinamensis*).
Wilson snipe (*Gallinago delicata*).
Woodcock (*Philohela minor*).
Upland plover (*Bartramia longicauda*).
Killdeer (*Oxyechus vociferus*).
Bobwhite (*Colinus virginianus*).
California quail (*Lophortyx californica*).
Ruffed grouse (*Bonasa umbellus*).
Mourning dove (*Zenaidura macroura carolinensis*).
Red-shouldered hawk (*Buteo lineatus*).
Red-tailed hawk (*Butêo borealis*).
Broad-winged hawk (*Buteo platypterus*).
Yellow-billed cuckoo (*Coccyzus americanus*).
Black-billed cuckoo (*Coccyzus erythrophthalmus*).
Red-cockaded woodpecker (*Dryobates borealis*).
Downy woodpecker (*Dryobates pubescens*).
Hairy woodpecker (*Dryobates villosus*).
Arctic three-toed woodpecker (*Picoides arcticus*).
Yellow-bellied sapsucker (*Sphyrapicus varius*).
Pileated woodpecker (*Phlœotomus pileatus*).
Red-headed woodpecker (*Melanerpes erythrocephalus*).
Red-bellied woodpecker (*Centurus carolinus*).
Flicker (*Colaptes auratus luteus*).
Whippoorwill (*Antrostomus vociferus*).
Nighthawk (*Chordeiles virginianus*).
Texan nighthawk (*Chordeiles a. texensis*).
Ash-throated flycatcher (*Myiarchus cinerascens*).
Crested flycatcher (*Myiarchus crinitus*).
Scissor-tailed flycatcher (*Muscivora forficata*).
Kingbird (*Tyrannus tyrannus*).
Arkansas kingbird (*Tyrannus verticalis*).
Cassin's kingbird (*Tyrannus vociferans*).
Phoebe (*Sayornis phoebe*).
Black phoebe (*Sayornis nigricans*).
Say's phoebe (*Sayornis saya*).
Wood pewee (*Myiochanes virens*).
Western wood pewee (*Myiochanes richardsonii*).
Olive-sided flycatcher (*Nuttallornis borealis*).
Western flycatcher (*Empidonax difficilis.*)
Least flycatcher (*Empidonax minimus*).
Traill's flycatcher (*Empidonax traill*i).
Yellow-bellied flycatcher (*Empidonax flaviventris*).
Acadian flycatcher (*Empidonax virescens*).
Horned lark (*Otocoris alpestris*).
Blue jay (*Cyanocitta cristata*).
Steller's jay (*Cyanocitta stelleri*).
California jay (*Aphelocoma californica*).
Crow (*Corvus brachyrhynchos*).
Bobolink (*Dolichonyx oryzivorus*).
Cowbird (*Molothrus ater*).
Yellow-headed blackbird (*Xanthocephalus xanthocephalus*).
Bicolored red-wing (*Agelaius gubernator californicus*).
Red-winged blackbird (*Agelaius phœniceus*).
Meadowlark (*Sturnella magna*).
Baltimore oriole (*Icterus galbula*).
Bullock's oriole (*Icterus bullocki*).
Orchard oriole (*Icterus spurius*).
Rusty blackbird (*Euphagus carolinus*).
Brewer's blackbird (*Euphagus cyanocephalus*).
Purple grackle (*Quiscalus q. quiscula*).
Great-tailed grackle (*Megaquiscalus major*).

English sparrow (*Passer domesticus*).
Vesper sparrow (*Poœcetes gramineus*).
Henslow's sparrow (*Passerherbulus henslowi*).
Sharp-tailed sparrow (*Passerherbulus caudacutus*).
Sandwich sparrow (*Passerculus sandwichensis*).
Ipswich sparrow (*Passerculus princeps*).
Grasshopper sparrow (*Ammodramus s. australis*).
Lark sparrow (*Chondestes grammacus*).
White-throated sparrow (*Zonotrichia albicollis*).
White-crowned sparrow (*Zonotrichia leucophrys*).
Field sparrow (*Spizella pusilla*).
Chipping sparrow (*Spizella passerina*).
Junco (*Junco hyemalis*).
Lincoln's sparrow (*Melospiza lincolni*).
Song sparrow (*Melospiza melodia*).
Fox sparrow (*Passerella iliaca*).
Chewink (*Pipilo erythrophthalmus*).
California towhee (*Pipilo f. crissalis*).
Spurred towhee (*Pipilo m. montanus*).
Cardinal (*Cardinalis cardinalis*).
Rose-breasted grosbeak (*Zamelodia ludoviciana*).
Black-headed grosbeak (*Zamelodia melanocephala*).
Blue grosbeak (*Guiraca cœrulea*).
Indigo bunting (*Passerina cyanea*).
Lazuli bunting (*Passerina amœna*).
Painted bunting (*Passerina ciris*).
Dickcissel (*Spiza americana*).

In the desert regions of the Northwest a small lizard (*Phrynosoma douglasii douglasii*, fig. 8), locally called the "sand toad," eats the adult Elateridæ in large numbers. A pair of these small lizards kept in the insectary would eat *Corymbites inflatus* beetles as fast as these could be fed to them. That this is a large part of their natural food is evidenced by the contents of the stomachs of three of these lizards collected at Govan, Wash., on April 24, 1910. In the stomach of lizard No. 1, 60 per cent of the food was ants, 8 per cent click-beetles, and 30 per cent other beetles; in lizard No. 2, 90 per cent was click-beetles and 10 per cent ants; and in lizard No. 3, 75 per cent ants, 15 per cent click-beetles, and 10 per cent other beetles. Several other kinds of these lizards inhabit the more southern desert lands of the West and are usually called "horned toads" in these sections.

In rearing cages wireworms are often infested with small mites (Tyroglyphidæ). The writer received a shipment of Melanotus larvæ from Inman, Nebr., in April, 1912. This material when received was apparently free from any vermin. When examined again, on June 17 of that year, some of the larvæ were found to be badly infested with these mites in the hypopial stage. The mites were so close together on the last two segments of the wireworms' bodies that they gave the impression of an incrustation. On June 24 all the wireworms were infested with these mites. Mr. Pergande also found these mites on larvæ of *Melanotus communis* in his cages at Washington, D. C., in March, 1900.[1] Mr. Banks is of the opinion that these mites are not attacking the wireworms, but merely make use of insects as a ready means of dispersal. He is evidently correct in

[1] U. S. Dept. Agr., Div. Ent., Notes, v. 4, No. 2884, Oct. 9, 1882.

this opinion, as the larvæ in question from Inman, Nebr., are alive at the present writing (October, 1914).

A gamasid was found attached to the body of an adult of *Alaus oculatus* at St. Louis, Mo., by Mr. E. R. Fisher. This mite was under the wing covers.[1] Another mite (*Chelifer alaus*) is recorded[2] as a parasite of the adult *Alaus oculatus*.

The writer has published[3] a record of a fly (*Thereva egressa* Coq.) the larva of which actually attacks and feeds upon wireworms. The larva was found in a wheat field near Pullman, Wash., and when found had its head and first four anterior joints within the body of a wireworm and was eating out the insides. This larva was brought into the insectary and fed upon wireworms, of which it ate usually two a day. On June 10 it pupated, and on June 24 the adult fly emerged. Two other species of Therevidæ (*Psilocephala aldrichii* Coq. and *P. munda Coq.*) were reared by the writer from larvæ taken in the field, associated with wireworms, in the Pacific Northwest. These flies in their larval stages are probably predaceous on elaterid larvæ. Forbes mentions[4] rearing a parasitic fly from an elaterid larva. A Proctotrupes has been reared from an elaterid larva in England by Curtis.[5] In the same work Curtis refers to a similar record by Bierkander.

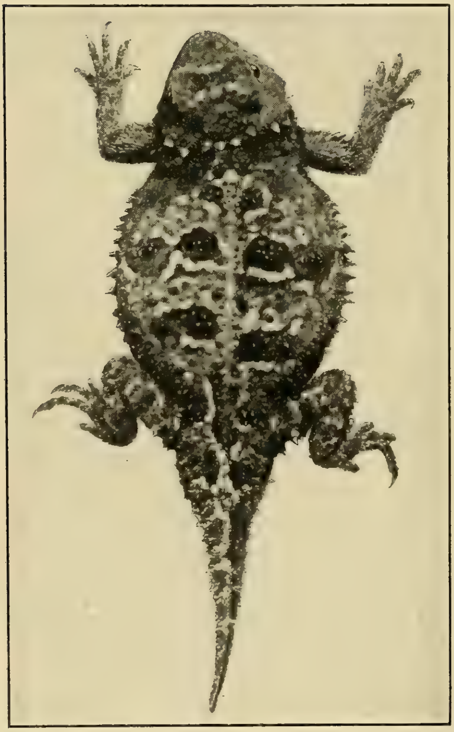

FIG. 8.—A horned toad (*Phrynosoma douglasii douglasii*), an enemy of the western wireworms. (Original.)

[1] U. S. Dept. Agr., Div. Ent., Note 165R, July 21, 1889.

[2] Leidy, J. Remarks on the seventeen-year locust, the Hessian fly, and a Chelifer. *In* Proc. Acad. Nat. Sci. Phila. [v. 29], 1877, p. 260–261, June 19, 1877.

[3] Hyslop, J. A. *Therera egressa.* *In* Proc. Ent. Soc. Wash., v. 12, No. 2, p. 98, June 15, 1910.

[4] Forbes, S. A. Insects Insects to the Seed and Root of Indian Corn. Univ. of Ill. Agr. Exp. Sta., Bul. 44, p. 228, May, 1896.

[5] Curtis, John. Farm Insects, p. 181. London, 1860.

Bierkander obtained through a correspondent a Filaria from a wireworm.[1] The author found a skin of a Melanotus larva firmly attached to the pupa case of a hymenopteron from which the parasite had emerged. The case was very similar to that of *Typhia* sp.

Several records have been made of elaterid larvæ being attacked by fungous diseases. An interesting note is made by Girard[2] in which he records Cordyceps attacking wireworms in Trinidad. A note in the files of this office[3] records a larva of *Agriotes* sp. received from Halifax, Nova Scotia, and placed in a rearing cage in the insectary at Washington, as being found later dead and filled with the mycelium of a fungus which Dr. Flora W. Patterson, of the Bureau of Plant Industry, determined as *Penicillium anisopliæ* Viull. This fungus is known as a parasitic disease of other insects and without doubt killed the larva in question. Comstock records[4] larvæ in his rearing cages being killed by *Metarrhizium anisopliæ.*

The writer found a larva of *Corymbites inflatus* in a rearing cage at the laboratory in Pullman, Wash., which had evidently been killed by a parasitic fungus. It was filled with white mycelium, which distended the body and even grew out between the segments. The specimen was sent in to Washington, but was received in too poor condition for determination.

Early in June, 1913, a large amount of the culture of the white-grub fungus (*Metarrhizium anisopliæ*) was sent to the writer by Mr. J. J. Davis. This material was introduced into a field at Nisbet, Pa. On revisiting the inoculated field on July 14 of that year, a larva of Melanotus was found dead and completely covered with a green fungus. This specimen was sent to Mr. Davis, who tentatively determined the fungus as *M. anisopliæ.* From this culture material the insectary room at the Hagerstown Laboratory became infected, and during the past summer, despite all precautions, at least one-half of the Elateridæ in our rearing cages were killed by this disease.

REMEDIAL MEASURES.

Remedial measures have been given with each of the more important wireworms treated in this paper. Here we wish to report on a number of measures that have been suggested from time to time as efficient in combating these insects. We have actually tried most of these measures, and to prevent repetition of these more or less costly experiments we publish here the results.

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[1] Gardner's Chronicle, London [v. 3], p. 433, June 24, 1843.

[2] Girard, A. Une nouvelle espèce d'Entomophyte. *Cordyceps hunti,* n. sp. (Champignon), parasite d'une larve d'Elateride. *In* Ann. Soc. Ent. France, Bul. des seances, 1895, p. CLXXXI–CLXXXII.

[3] U. S. Dept. Agr., Bur. Ent., Webster Note No. 4751.

[4] Comstock, J. H., and Slingerland, M. V. Wireworms. N. Y. Cornell Univ. Agr. Exp. Sta., Bul. 33, p. 211, November, 1891.

Remedial measures may be classified under three headings: (1) Seed treatment to prevent insects eating the seed; (2) introduction of poisonous or noxious substances into the soil; and (3) cultural methods.

TREATMENT OF SEED.

Under the first head many substances have been used and reported as more or less efficient, among which might be mentioned Paris green and coal tar, gas tar, coal oil, tar, Paris green, and arsenate of lead. In 1884 Webster used kerosene as a treatment of seed corn to protect seed from wireworms. Although his experiment did not apparently impair the vitality of the seed, a farmer who attempted to apply the recommendation claimed that the vitality of the seed was destroyed thereby. In 1888 Forbes treated corn seed with Paris green, and though wireworms fed on corn so thoroughly coated as to be quite green they seemed to experience no ill effects. He also experimented with alcoholic solutions of arsenic and water solutions of strychnine and potassium cyanid.

In the spring of 1911 wireworms were very numerous on the wheat land at Wilbur, Wash., and the writer carried on a series of very extensive experiments to determine the value of some of these substances and also added a few which, to his knowledge, had not been tried before.

Three sacks of wheat (6 bushels) were treated on March 24 with arsenate of lead. Six pounds of insecticide were used for the batch. The arsenate was thinned to the consistency of thick whitewash, with water, and thoroughly mixed into the seed in a large box. The seed, when dry, was very white and well coated. On the same date two sacks (4 bushels) were treated with coal tar. The tar was applied with a paddle, the paddle being first dipped into the tar and then stirred around in the wheat until the seed was well coated. The seed was then mixed with sand and allowed to dry. One sack of wheat was treated with strychnine, 2 ounces of this poison being used to 2 bushels of wheat. The strychnine was dissolved in 2 quarts of hot water and 1 pound of sugar was added as an adhesive. The seed was then soaked in this liquid and allowed to dry. On March 31 all of these treated batches of seed were sown. The sowings were made in plats which were about half a mile long. They were made in an 11-foot wheat seeder, and were arranged as follows:

2 seeder widths of seed treated with strychnine.
2 seeder widths without treatment, as a check.
2 seeder widths of seed treated with coal tar.
4 seeder widths check.
5 seeder widths of seed treated with lead arsenate.
5 seeder widths check.
3 seeder widths of seed treated with coal tar.
9 seeder widths check.
4 seeder widths of seed treated with arsenate of lead.

These plats were carefully staked and examined from time to time, but at no time could any appreciable difference be noted as to their appearance. Wireworms were as numerous in all the treated plats as in the checks. Wheat was very generally attacked and no dead wireworms were found.

A number of wireworms were confined in a large tin cage with wheat treated with strychnine as their only food. After two months these larvæ were still alive and apparently unaffected by the poison, though they ate the poisoned grain.

While these experiments were going on at Wilbur a more intensive series was being carried on at Spokane. Here, instead of wheat, sweet corn was used. These experiments were carried on in a field recently cleared of timber. The soil was quite heavy and very moist. Wireworms were very numerous and apparently quite generally distributed.

On April 5, seed corn was treated in the following manner:

Lot 1. Coal tar was applied very heavily and Paris green dusted onto it until it was quite green.

Lot 2 was treated by soaking for a few minutes in copper sulphate and then drying rapidly in the sun. Several potatoes also were soaked, cut into small pieces, in a saturated solution of strychnine.

This field was all in corn in 1909 and was badly infested with wireworms. In 1910 it was half in wheat on fall plowing and half in potatoes on spring plowing, and was also badly infested this year with wireworms. A plat of each treatment with a check row between each plat was planted on each half of the field. Seventy hills of corn were in each plat. All the plantings were made on April 24. The coal-tar treatment prevented about 90 per cent of the seed so treated from germinating, so this precludes the use, at least as applied to this experiment, of this seed treatment. On May 2 the hills were dug out and the wireworms in each hill counted. Wherever wireworms were present they were attacking the seed. The results of this count appear in Table I:

Table I.—*Results of experiments against wireworms with treated seed.*

Row.	Treatment.	Number of hills examined.	Number of wireworms found.	Number of wireworms per hill (average).	Total average number of wireworms per hill for each treatment.
1	Copper sulphate	10	40	4	
11	do	24	138	5.75	4.87
5	Coal tar and Paris green	24			
7	do	24			
2	Check	3			
4	do	24	35	1.458	
6	do	24	40	1.667	
8	do	13	22	1.692	
10	do	24	93	3.875	1.758

From the last experiment we conclude that the use of coal tar and Paris green is not a remedial measure to be recommended. However, Dr. H. T. Fernald has published[1] an account of a series of experiments that seem to reach quite the opposite conclusion, and it is very probable that gas tar will not prevent germination as did the coal tar of our experiments.

The copper-sulphate plat was more severely infested than the check plats, so this treatment is quite useless as an insecticide for wireworms. The potato bait poisoned with strychnine was a failure because the potatoes were allowed to dry up before being placed in the ground.

Mr. G. I. Reeves carried on an experiment at Pullman, Wash., using a commercial tobacco extract applied to the seed corn as a repellent. This experiment was carried on in a root cage. On May 27, 1909, he treated 15 kernels of seed corn by soaking for 24 hours in a solution of commercial tobacco extract, 1 part to 16 parts of water. The seed was dried before planting and was sown with alternate untreated seeds as a check. Wireworms were introduced at the time of seeding and also on June 2. The experiment was discontinued on June 10, and all the seed carefully examined. Of the treated seeds, eight were eaten into by wireworms, while nine of the untreated seeds were destroyed. It is very evident from this experiment that tobacco solution as a repellent is quite useless, at least for wireworms.

Soaking the seed in formalin has been suggested as a means of repelling wireworms. This measure is quite useless. In the regions of the Pacific Northwest where the author was studying severe wireworm outbreaks nearly all the seed wheat had been treated with formalin as a means of preventing the development of smut fungus.

Mr. O. A. Johannsen and Miss Edith M. Patch have published[2] the results of a series of experiments carried on in Maine. They treated seed corn with tar and Paris green, and with arsenate of lead, and found both of these treatments inefficient.

SOIL TREATMENT.

The second group of remedial measures—soil treatment—has received considerable attention. Experiments with soil fumigants are now being carried on by the writer, but as the methods have not as yet been placed on a practical basis this matter will not be treated herein.

[1] Fernald, H. T. A new treatment for wireworms. *In* Jour. Econ. Ent., v. 2, No. 4, p. 279–280, August, 1909.

[2] Johannsen, O. A., and Patch, Edith M. Insect Notes for 1911. Maine Agr. Exp. Sta., Bul. 195, p. 229–248, December, 1911.

Webster carried on experiments at Cedarville, Ohio, in 1894 to determine the effectiveness of kainit as an insecticide. The fertilizer was applied at the rate of 500 pounds to the acre without any effect whatever. He also carried on a series of experiments at La Fayette, Ind., in 1889, to test the efficiency of an often-recommended substance—table salt. Pots were used in these experiments, and table salt applied to the surface and washed in with water. Three dosages were used at the rate of about 500 pounds, 1,000 pounds, and 25,000 pounds per acre, respectively, and in no case were wireworms killed by the application.

The Maine experiment station has tried a patented preparation composed largely of slaked lime, a "soil fungicide," and tobacco dust, applied to the hills in cornfields infested with wireworms, and has found all of these treatments quite useless. Experiments [1] with chlorid of lime, gas lime, chlorate of potash, bisulphid of carbon, crude petroleum, kerosene, and emulsions of crude petroleum and kerosene, applied to the soil, have demonstrated that none of these substances is of practical value in destroying wireworms. However, the use of petroleum products as soil sterilizers is suggestive, and will be further investigated.

Mr. J. J. Davis [2] has found that a soil fumigant highly recommended by some English entomologists is quite useless in combating *Limonius confusus*.

CULTURAL METHODS.

The third group of remedial measures—cultural methods—is the only one which so far has been actually proved to be of practical value.

Flooding land where irrigation is practiced would be of little avail unless long continued, as we have records of severe outbreaks of wireworms on land in Indiana that is annually overflowed by the rivers. Fall plowing is of but little use in combating these insects. The cornfields so severely attacked by the wheat wireworm at Bridgeport last year had been plowed in the spring. The garden patch, however, was fall plowed, and potatoes on this patch were absolutely destroyed by wireworms. Another piece of fall-plowed land on another part of the farm planted to corn was practically free from worms, which illustrates how easily faulty conclusions can be arrived at, with insufficient data. Mr. O. A. Johannsen and Miss Edith Patch record observations made at Monmouth, Me., in 1911, wherein a field was plowed after the ground

[1] Comstock, J. H., and Slingerland, M. V. Wireworms. N. Y. Cornell Univ. Agr. Exp. Sta., Bul. 33, November, 1891.

[2] Davis, J. J. Insect notes from Illinois for 1909. *In* Jour. Econ. Ent., v. 3, No. 2, p. 182, April, 1910.

had been stiffened by frost in the fall, and which was so badly infested the following spring that the crops were absolutely destroyed.

The fatality to the beetles caused by the destruction of the pupal cell in the fall has been apparently somewhat overdrawn. In our cages at the field station at Hagerstown, Md., we had, in March, 1914, many adults of *Agriotes mancus* alive in cages wherein they were subjected to outdoor weather conditions. These adults were removed from their pupal cells during September, 1913.

Two other remedial measures have been suggested from time to time, the first of which is trapping the larvæ in potato and other vegetable baits and hand killing; the second is killing the adults with poisoned bait of several kinds—clover, sweetened liquids, bran mash, potatoes and other vegetables, and rape cake. Miss Ormerod found a true rape-seed cake quite useless, but reports[1] "Kurrachee cake," made from mustard seed, as killing the larvæ which fed upon it. These methods have been found very inefficient, and even were they successful in killing the insects they would be impractical so far as the extensive cereal and forage crops are concerned.

[1] Proc. Ent. Soc. London, 1882, p. xix.

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BULLETIN OF THE U.S. DEPARTMENT OF AGRICULTURE

No. 157

Contribution from the Bureau of Plant Industry, Wm. A. Taylor, Chief.
January 21, 1915.

TILLAGE AND ROTATION EXPERIMENTS AT NEPHI, UTAH.[1]

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(In cooperation with the Utah Agricultural Experiment Station.)

INTRODUCTION.

The experimental work at the Nephi (Utah) substation has been conducted cooperatively since 1907 by the Office of Cereal Investigations of the Bureau of Plant Industry and the Utah Agricultural Experiment Station. The memorandum of understanding between these two parties specifies that "the objects of these cooperative investigations shall be (1) to improve the cereals of the intermountain region by introducing or producing better varieties than those now grown, especially with regard to drought resistance, yield, quality, earliness, etc.; (2) to conduct such other experiments as might seem advisable for the accomplishment of the greatest possible good to the dry-land interests of the State." Most of the experiments which have been conducted have dealt directly with cereal investigations as specified in the first clause of the memorandum of understanding; but, as provided in clause 2 of this memorandum, a number of experiments have been carried on with methods of tillage and with minor dry-land crops.

A preliminary report of all the work at Nephi was published in 1910.[2] This report was rather general in its nature, owing to the

[1] The Nephi substation was established in 1903 by the Utah Agricultural Experiment Station. From that time until July 1, 1907, it was operated as one of several "county farms" located at various points in the State. Prof. L. A. Merrill, agronomist of the Utah station, directed the work from 1903 to 1905. Thereafter until 1907 it was under the direction of Prof. W. M. Jardine, agronomist of the Utah station. On July 1, 1907, cooperation between the Utah experiment station and the Bureau of Plant Industry was effected, and Mr. F. D. Farrell, of the U. S. Department of Agriculture, was placed in charge of the substation. He was succeeded on March 15, 1910, by Mr. P. V. Cardon. From the time of the establishment of the station until July 1, 1912, at which time he was succeeded by Mr. A. D. Ellison, Mr. Stephen Boswell was foreman. From 1907 to 1912 the State of Utah has been represented through Prof. L. A. Merrill, agronomist in charge of arid farms. On July 1, 1913, Mr. Ellison succeeded Mr. Cardon as superintendent, and Dr. F. S. Harris, agronomist of the Utah station, succeeded Prof. Merrill.

[2] Farrell, F. D. Dry-land grains in the Great Basin. U. S. Dept. Agr., Bur. Plant Indus. Cir. 61, 39 p., 2 pl., 1910.

Note.—This bulletin should be of interest to agronomists and to dry-land farmers, particularly in the Great Basin area.

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fact that the experiments had been conducted during only a brief period and no conclusive results were available. In 1913 a detailed report of varietal and improvement work with cereals was issued.[1] The present bulletin presents the results of the cultivation experiments with dry-land cereals.

DESCRIPTION OF THE SUBSTATION.

A detailed description of the Nephi substation and a full discussion of the climatological data collected there were given in a previous publication;[1] hence, only a brief description of the substation will be given here, and, except in special cases, the climatological factors will not be considered further than to give general averages.

LOCATION.

The Nephi substation is located 6 miles south of Nephi, in the eastern part of Juab County, Utah, near the center of the State. It comprises 100 acres of land lying near the top of the north slope of the Levan Ridge, which transversely crosses the Juab Valley. The top of this ridge is approximately 6,000 feet above sea level and about 500 feet higher than the bottom of the valley. When the substation was located in 1903, the Levan Ridge was covered with a dense growth of sagebrush, from 2 to 5 feet in height. Now, dry farming is practiced generally on the ridge and from 150,000 to 175,000 bushels of winter wheat are produced annually in the vicinity of the substation.

SOIL.

The soil of the substation, like most soils of the Great Basin, is alluvial and very deep. It is reddish brown in color and varies in texture from clay loam to sandy loam, the latter appearing most generally beneath the 4-foot level. Above this level the soil contains about 15 per cent of clay. This comparatively high percentage of clay makes the soil "heavy" and rather difficult to work under certain conditions. In wet weather it becomes very sticky, while in extremely dry weather that on which a crop has been grown becomes very hard. The preparation of a good seed bed, however, usually is not difficult.

RAINFALL.

The average annual precipitation at the Nephi substation for 1898 to 1913, inclusive, was 13.4 inches. During this period the annual precipitation was above normal 6 years and below normal 10 years. The wettest year was 1906, with 18.48 inches precipitation; the driest year was 1910, with 9.08 inches. During the progress of the experiments reported herein, the annual precipitation was above

[1] Cardon, P. V. Cereal investigations at the Nephi substation. U. S. Dept. Agr. Bul. 30, 50 p., 9 figs., 1913.

normal in 1908 and 1909, with 16.66 and 16.19 inches, respectively; while in 1910, 1911, 1912, and 1913 it was below normal, with 9.08, 10.11, 12.61, and 12.34 inches, respectively. The average annual precipitation for these last four years was only 11.03 inches.

Most of the annual precipitation of the past 16 years has fallen during the months of March, April, and May, the latter month having the highest average. The months of June and July have been by far the driest months. A large part of the precipitation from November to March, inclusive, has fallen in the form of snow.

Most of the rainstorms at Nephi have been small and generally almost negligible. This is especially true of the storms which have occurred from March to August, inclusive. Such showers are of little value to the crops, because they fall upon a hot, dry surface and the moisture is soon lost by evaporation. It has been observed that showers of less than 0.5 inch are of little value when considered singly. When wet days follow each other consecutively, however, thus reducing the evaporation and leaving the surface soil wet, a fall of even 0.5 inch of rain is of value.

EVAPORATION.[1]

The average evaporation at Nephi during the six months from April to September, inclusive, has been about 45 inches. The lowest total evaporation, 40.53 inches, was recorded in 1909; the highest, 50.26 inches, was recorded in 1910. The lowest average daily evaporation has been recorded in April and the highest in July; however, there was little difference in the evaporation of June, July, and August.

WIND.

Strong winds or protracted hot winds are practically unknown in the vicinity of the Nephi substation, while many summer days pass without any appreciable movement in the atmosphere. When wind does blow, it is usually from the south or southwest in the morning, changing gradually during the day until by evening it is blowing from the north or northwest. The average velocity for any one day seldom reaches 10 miles an hour.

TEMPERATURE.

The highest mean and maximum monthly temperatures during the growing season have been recorded in July, while the lowest have been recorded in April and October. No records have been kept from November to March, inclusive. Comparatively low temperatures are reached in winter, sometimes as low as $-20°$ F., but serious injury to the fall-sown crops does not result if the ground is covered

[1] Instruments for measuring evaporation, wind velocity, and temperature, and the apparatus used in making soil-moisture determinations were furnished by the Biophysical Laboratory of the Bureau of Plant Industry, which is cooperating in the work at Nephi.

with snow. When there is no snow, however, winterkilling of fall-sown cereals is not uncommon.

Only two months of the year, July and August, have been free from frost. Normally, however, there are from 90 to 100 days in the frost-free period, extending from June 15 to September 15.

EXPERIMENTAL WORK.

All experiments were conducted under field conditions, the treatment differing from common farm practice only in the tillage method under test.

DESCRIPTION OF PLATS.

Rectangular tenth-acre plats were used for all experiments except one, in which fifth-acre plats were used. The tenth-acre plats were 36 by 121 feet, while the fifth-acre plats were 72 by 121 feet. The plats lay in series running north and south. The series were in pairs, the two in each pair being separated from each other by a 5-foot alley, while between the pairs of series there were roads 13 feet wide. The plats within each series were separated by 5-foot alleys. Thus, each plat was separated from the others by a 5-foot alley on two sides and one end and by a 13-foot road on the other end.

Two sets of plats were used for each experiment, except in the case of the continuous-cropping test. These two sets of plats permitted the alternate cropping and fallowing of each plat, a practice which was followed regularly.

SOIL-MOISTURE DATA.

Soil-moisture data were collected on most fallow plats and on some cropped plats. The number of samples taken varied with the plan of the experiment. Soil tubes were used in sampling, the soil being taken out in foot sections to depths of 6 to 10 feet. Each foot section was placed in a soil can, which was immediately covered with a close-fitting lid and taken soon after to the laboratory. From two to four cores were taken from each plat on each day that it was sampled.

The moist weight of each sample was obtained soon after its arrival in the laboratory. In no case was the weighing delayed more than half a day, the sampling usually being done in the forenoon and the weighing in the afternoon. After the moist weights were obtained, the samples were placed in an asbestos-board oven, where they were subjected to an average temperature of 110° C. They were left in the oven until constant weight was reached and then the dry weight of each sample was determined. The difference between the moist and the dry weights of the sample was then divided by the dry weight of the sample, to get the percentage of moisture. An average of the moisture content of all samples taken on a plat was considered the average moisture content of the plat.

TREATMENT OF THE CROP.

Methods employed.—The Turkey winter wheat (C. I. No. 2998), a hard, red variety, was used in all the experiments except where otherwise stated. Except in the tests dealing directly with seeding problems, the plats of each test were sown on the same date, at a uniform depth, and at a uniform rate (3 pecks per acre). After seeding, no cultivation was given until the following spring. Then, if deemed advisable, the plats were harrowed with a spike-tooth harrow to break the crust, which usually had formed as a result of conditions in winter and early spring. The breaking of the crust was intended to check evaporation and to stimulate the plants. One harrowing was usually all the cultivation the crops received. Occasionally, however, weeding was necessary, and when hoes were used such weeding might be considered as cultivation.

The crops were harvested with a binder, each plat being cut separately, usually when the grain was in the "hard-dough" stage. The bundles were always shocked, and then the plat was raked in order to prevent loss from fallen heads. The shocks generally stood in the field from three to four weeks before thrashing commenced.

The grain of each plat was thrashed separately. Before thrashing, the entire crop was weighed. The weight of the grain after thrashing was subtracted from the total weight of the crop, thus giving the weight of straw per plat. The weight of straw or grain, multiplied by 5 or 10, according to the size of the plat, gave the yield per acre. The acre yield of grain in pounds was then divided by the standard weight per bushel to get the yield per acre in bushels.

Sequence of operations.—The experiments here reported will be discussed in the following order, which is based upon their relation to the sequence of operations necessary to dry-land crop production: Stubble treatment after harvest, plowing, cultivation of fallow, seeding the crop, cultivation of the crop, harvesting the crop, frequency of cropping, and diversity of the crops in the rotation.

STUBBLE TREATMENT AFTER HARVEST.

In ordinary practice in this region no cultivation precedes the plowing of the plats; however, to determine the value of different methods of treating the stubble land previous to the time of plowing, two tests were inaugurated in the fall of 1911. These tests have been (1) the burning of the stubble, as compared with plowing it under; and (2) the disking of the stubble immediately after harvest, as compared with no treatment of the stubble previous to plowing. Neither of these tests has been in progress long enough to give any dependable information.

PLOWING.

In the plowing experiments at the Nephi substation comparisons have been made between spring and fall plowing; subsoiling, deep plowing, and shallow plowing; also between deep fall plowing followed by shallow spring plowing and shallow fall plowing followed by deep spring plowing. Most of the experiments have been in progress since 1908, and enough data are available to warrant a rather full discussion at this time.

Fall and Spring Plowing.

Since the test of fall and spring plowing was commenced in the fall of 1908, four tenth-acre plats have been used, thus permitting the practice of alternately cropping and fallowing the plats. The use made of each plat in each year since 1908 is shown in Table I.

Table I.—*Use of plats at the Nephi substation for the years 1908 to 1913, inclusive.*

Plat.	1908	1909	1910	1911	1912	1913
12A	Winter wheat.	Fallow	Winter wheat.	Fallow	Winter wheat.	Fallow.
13A	do	do	do	do	do	Do.
15D	Fallow	Winter wheat.	Fallow	Winter wheat.	Fallow	Winter wheat.
16D	do	do	do	do	do	Do.

From 1904 to 1908 the plats were alternately fallowed and cropped to winter wheat in the same manner indicated above. During these four years all plats received practically uniform treatment, being plowed in the fall and allowed to lie until the spring of the following year, when they were double disked and harrowed and then fallowed, with normal treatment until seeding time in the fall.

In the fall of 1908 plat 13A was plowed as usual, while plat 12A was not plowed until the spring of 1909. During the summer of 1909 the plats received uniform treatment. In the fall of 1909 plats 15D and 16D were segregated as alternates to plats 12A and 13A in this experiment. Plat 16D was plowed in the fall and left without further cultivation until the following spring. Plat 15D was plowed in the spring of 1910. Both plats were fallow during 1910 and received the same cultivation.

It will be noticed that during the last four years each of the plats in this test has been fallow two summers and has produced two crops of winter wheat, a total of four crops; that each year there have been two fallow plats and two cropped plats; that one plat of each pair has been plowed in the fall and the other in the spring; and that subsequent treatment has been as nearly the same in all cases as possible.

In studying the relative value of spring and fall plowing, moisture conservation, yield per acre, and cost of production have been used as bases of comparison.

MOISTURE CONTENT OF FALLOW.

Much of the argument in favor of fall plowing has been based upon the belief that the rough surface of fall-plowed land is in better condition than unplowed stubble land for absorbing the winter precipitation. For the purpose of determining the accuracy of this theory, soil-moisture studies were made in connection with the experiment discussed here. Soil samples were taken to a depth of 6 feet from each fallow plat at the beginning, in the middle, and at the end of the season, and the moisture content of each foot section was determined, as previously described in this bulletin. The data thus collected during the four years from 1909 to 1912, inclusive, are presented in Table II, which shows the annual and average percentages of moisture in each foot of soil and the average percentages in the first 6 feet of soil on each of the fallow plats in April, June, and September.

TABLE II.—*Annual and average percentages of moisture for each of the first 6 feet of soil in fallow plats in a test of spring plowing compared with fall plowing at the Nephi substation, samples taken in April, June, and September, for the years 1909 to 1912, inclusive.*

Season and depth of sampling.	Date of determination.														
	1909			1910			1911			1912			Four-year average.		
	Apr. 5.	June 26.	Sept. 18.	Apr. 12.	June 24.	Sept. 1.	Apr. 17.	June 12.	Sept. 21.	Apr. 25.	June 26.	Sept. 16.	Apr.	June.	Sept.
Spring plowing:															
1 foot	20.60	15.90	17.05	21.27	12.35	11.88	20.48	15.86	13.09	14.98	14.18	12.59	19.33	14.57	13.65
2 feet	20.37	19.45	19.00	21.25	18.93	18.38	19.57	19.36	18.10	22.65	19.80	19.47	20.96	19.38	18.74
3 feet	20.10	18.80	20.45	20.50	18.70	17.65	21.02	19.09	16.93	21.88	19.70	19.55	20.87	19.07	18.64
4 feet	20.10	19.10	20.15	21.07	18.48	15.78	19.34	17.78	17.12	22.55	20.50	19.63	20.76	18.96	18.17
5 feet	18.70	19.17	19.10	21.40	20.10	16.88	17.04	16.69	15.34	22.07	20.34	17.80	19.80	19.08	17.28
6 feet	19.30	19.05	18.40	19.05	18.80	17.80	17.20	17.78	17.73	18.60	18.20	15.05	18.54	18.46	17.24
Average	19.86	18.58	19.02	20.76	17.89	16.40	19.11	17.76	16.38	20.46	18.79	17.35	20.04	18.25	17.29
Fall plowing:															
1 foot	21.10	14.60	17.65	20.93	14.45	12.83	21.29	17.98	12.26	21.55	15.82	13.29	21.22	15.71	14.01
2 feet	20.92	19.60	17.60	20.88	19.48	18.05	21.59	19.60	17.76	21.45	19.63	18.67	21.21	19.58	18.02
3 feet	20.00	19.60	19.05	20.13	18.20	17.83	20.03	17.55	17.43	19.62	18.25	18.13	19.94	18.40	18.11
4 feet	19.80	18.85	18.95	19.80	19.25	17.75	15.24	14.76	15.76	12.82	15.21	15.45	16.91	17.02	16.98
5 feet	17.97	17.90	17.75	19.10	18.55	17.05	16.13	14.79	14.95	11.39	13.30	12.40	16.15	16.13	15.54
6 feet	18.65	20.32	19.30	19.57	19.80	16.98	18.78	16.75	15.25	14.99	18.40	14.49	18.00	18.82	16.50
Average	19.74	18.48	18.38	20.07	18.29	16.75	18.85	16.90	15.57	16.97	16.77	15.41	18.90	17.61	16.53

Table II shows (1) that in every case except the second and third sampling of 1910 the average percentage of moisture in the 6 feet of soil was higher in the spring-plowed plat; (2) that the first foot of soil in the fall-plowed plat contained, as a rule, a higher percentage of moisture than the first foot of the spring-plowed plat; (3) that the slight difference in the moisture content of the second foot of the plats favored the fall-plowed plat during the spring and summer, while it favored the spring-plowed plat at seeding time in the fall;

(4) that the average moisture content of the third, fourth, and fifth feet was invariably in favor of the spring-plowed plat; (5) that there

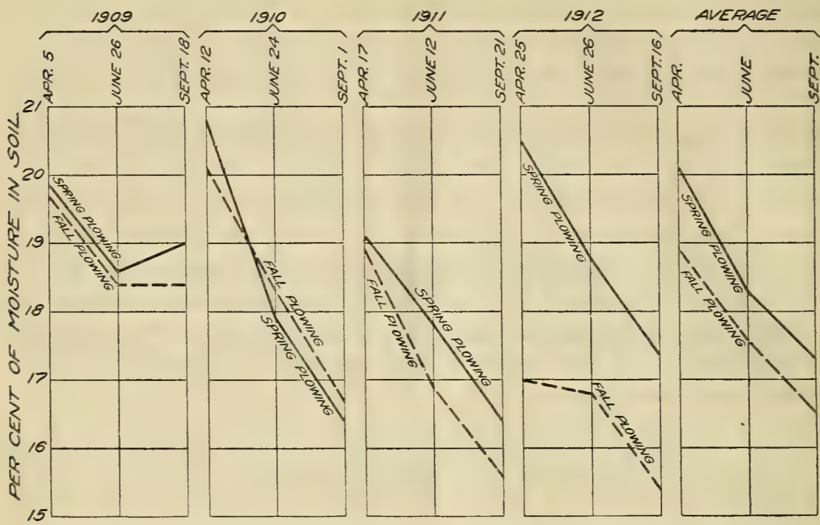

FIG. 1.—Graphs showing the average percentage of moisture in the first 6 feet of soil at the beginning, in the middle, and at the end of the fallow season, as found in the spring-plowing and fall-plowing tests at the Nephi substation, 1909 to 1912, inclusive.

was little difference in the moisture content of the samples of the sixth foot; and (6) that the loss of moisture from spring to fall was

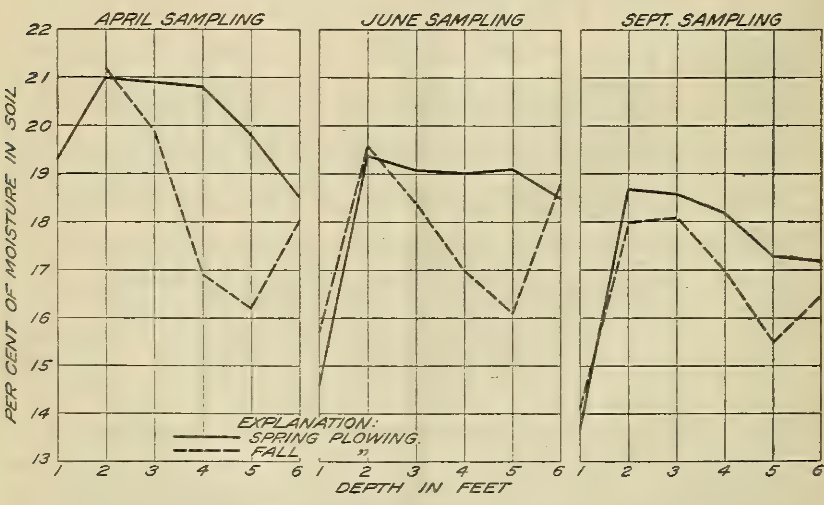

FIG. 2.—Graphs comparing the average percentage of moisture in each of the upper 6 feet of soil at the beginning, in the middle, and at the end of the fallow season, as found in the spring-plowing and fall-plowing tests at the Nephi substation, 1909 to 1912, inclusive.

about the same on both plats. These facts are shown graphically in figures 1, 2, and 3.

The facts thus brought out seem to indicate that at Nephi stubble land allows the winter precipitation to penetrate to greater depths than fall-plowed land and that the loose surface of the fall-plowed land retains more of the precipitation of winter than the compact surface of the stubble land. They indicate, further, that when the stubble land is plowed in the spring it loses much of the moisture in the surface foot, as does also the fall-plowed land when it is replowed or double disked, one of these operations always being necessary in the spring on fall-plowed land. This is decidedly to the disadvantage

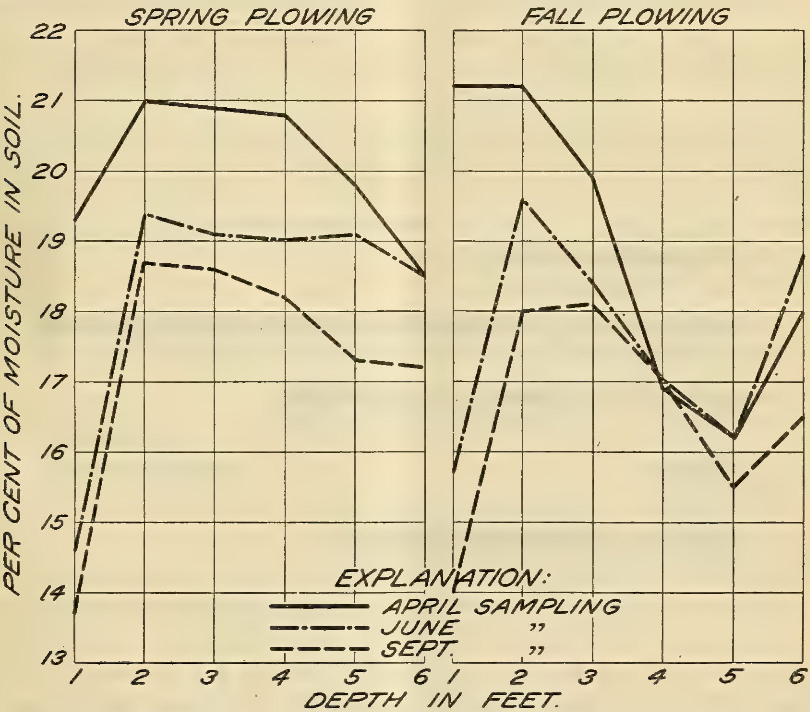

FIG. 3.—Graphs showing the average seasonal decline in percentage of moisture in each of the upper 6 feet of soil, as found in the spring-plowing and fall-plowing tests at the Nephi substation, 1909 to 1912, inclusive.

of the fall-plowed land, which during the winter retains so much moisture in the surface foot. Lastly, the facts brought out show that the moisture content of the soil below the surface foot was practically constant throughout the season. This was favorable to the spring-plowed land, which had allowed the moisture to penetrate into the third, fourth, and fifth feet. That winter wheat makes use of moisture found at these depths is evidenced by the fact that in 1910 the roots of a winter-wheat plant growing on the station were found to extend more than 7 feet below the surface of the ground. As the spring-plowed plats had some advantage in soil-moisture content below the second foot, the higher yields on these plats were anticipated.

YIELD OF GRAIN.

The annual and average yields of winter wheat in bushels per acre from 1910 to 1913, inclusive, are presented in Table III and are compared graphically in figure 4.

TABLE III.—*Annual and average yields of winter wheat from fall-plowed and spring-plowed plats at the Nephi substation, 1910 to 1913, inclusive.*

Treatment.	Yield per acre of grain (bushels).				
	1910	1911	1912	1913	Average.
Plowed in spring previous to seeding	14	33	22	5	18.5
Plowed in fall one year before seeding	12	29	22	4	16.8

The yields reported in Table III agree fairly with the moisture data reported in Table II. The average difference in yield of 1.7 bushels

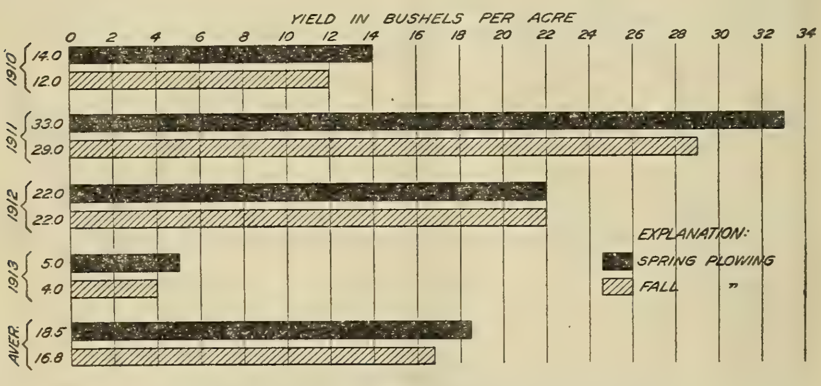

FIG. 4.—Diagram comparing the annual and average yields obtained in the spring-plowing and fall-plowing tests at the Nephi substation, 1910 to 1913, inclusive.

per acre favors spring plowing, which has given yields equal to or greater than fall plowing each year since the experiment began. This small difference in yield, however, is not so important in itself as it is when considered jointly with the cost of production.

RELATIVE COST OF FALL AND SPRING PLOWING.

Fall plowing is more difficult than spring plowing, and for this reason it generally costs more. The difference in cost at the substation has varied between 15 and 25 cents an acre, with an average of 20 cents. In addition to this, it has been observed that the plats which were spring plowed were more nearly free from weeds and volunteer grain during the fallow period than the plats plowed in the fall. It was always necessary to replow or double disk the fall-plowed plats in the spring, owing to a rather vigorous growth of weeds and volunteer grain. Even these operations often failed to destroy

all vegetative growth, so that, in order to keep the fallow clean, some weeding was necessary two or three times during the summer. It seems probable that fall plowing turns under weed seeds and grain kernels, some of which lie dormant until they are brought to the surface again the next spring by replowing or disking the land. Thus the operation which is intended to destroy all growth induces further growth by bringing other seeds into a position favorable to germination. Their growth requires frequent weeding of the fallow. These extra operations were unnecessary on the spring-plowed plats, and consequently the cost of producing crops on these plats was reduced to a point substantially below that on the fall-plowed plats.

The average cost of spring plowing was $1.93 per acre, while fall plowing cost $2.13. Replowing the fall-plowed land cost on an average $1.85 per acre, while double disking the fall-plowed land cost about 75 cents per acre, making an average cost of $1.30 and increasing the cost of fall plowing to $3.43. The subsequent weeding of the fall-plowed land cost about 25 cents per acre. This, added to the cost of plowing and replowing or double disking, makes the total cost of fall plowing $3.68, as compared with $1.93 for spring plowing, a difference of $1.75 per acre. These figures, of course, do not include the cost of cultivating the fallow, seeding and harvesting the crop, etc., which was the same on all plats and hence need not be considered here.

It has been shown that spring plowing has given an average yield of 1.7 bushels per acre more than fall plowing. The average market value of wheat at Nephi during the past four years has been 75 cents per bushel. Spring plowing, then, has yielded $1.28 more per acre than fall plowing. The extra income added to $1.75, the amount saved by spring plowing as compared with fall plowing, makes the difference in net return $3.03 per acre in favor of spring plowing.

The fact that spring plowing at the substation was done as early in the year as possible must receive emphasis at this point. The land at that time was in good condition for plowing, and it turned over in excellent shape. Later plowing was found to be less desirable. For this reason it might be advisable for farmers in distributing their farm labor to plow enough in the fall to allow them to plow all the rest of their land at the proper time in the spring. This practice is followed by many of the more successful farmers in the vicinity of Nephi.

Depth of Fall Plowing.

Previous to 1908 all of the eight plats used in the fall depth-of-plowing test were given treatment as nearly uniform as possible, being alternately fallowed and cropped to winter wheat. In the fall of 1908 four adjacent plats, 16A, 17A, 18A, and 19A, were set aside for this test. Alternate plats, 16C, 17C, 18C, and 19C, were added

in the fall of 1909. Since this time the plats have been alternately fallowed and cropped to winter wheat, receiving uniform treatment in every case except in the depth of plowing. They were replowed or double disked each year in order to destroy weeds and volunteer grain.

The depth of plowing on the different plats in the fall of 1908, 1910, and 1912 was as follows: 16A, subsoiled, 18 inches; 17A, subsoiled, 15 inches; 18A, plowed, 10 inches; 19A, plowed, 5 inches. The depth of plowing on the different plats in the fall of 1909, 1911, and 1913 was as follows: 16C, subsoiled, 18 inches; 17C, subsoiled, 15 inches; 18C, plowed, 10 inches; 19C, plowed, 5 inches.

TABLE IV.—*Annual and average percentages of moisture for each of the first 6 feet of soil in plats plowed to different depths at the Nephi substation, samples taken in April, June, and September, for the years 1909 to 1912, inclusive.*

Depth of sampling.	Date of determination.														
	1909			1910			1911			1912			Average.		
	Apr. 6.	June 28.	Sept. 23.	Apr. 13.	June 6.	Sept. 17.	Apr. 18.	June 15.	Sept. 11.	Apr. 29.	June 28.	Sept. 16.	Apr.	June.	Sept.
SUBSOILED 18 INCHES DEEP.															
1 foot	22.00	17.37	18.05	20.35	13.13	13.05	19.50	14.83	15.95	20.99	18.89	9.68	20.71	16.06	14.18
2 feet	21.40	21.35	20.40	20.70	19.48	19.80	20.45	18.41	17.79	21.71	20.98	18.51	21.07	20.06	19.13
3 feet	21.25	19.55	19.55	20.70	19.33	16.53	15.20	16.90	18.17	18.61	19.60	17.38	18.94	18.85	17.91
4 feet	20.00	19.45	19.00	19.95	18.38	17.65	13.19	14.63	17.08	12.95	16.65	14.98	16.52	17.28	17.18
5 feet	19.05	19.50	18.65	19.15	17.83	17.83	14.72	15.51	16.30	13.35	14.64	10.48	16.57	16.87	15.82
6 feet	19.50	20.22	20.60	20.03	18.75	18.93	16.58	17.79	17.46	12.47	17.89	15.91	17.15	18.66	18.23
Average	20.53	19.57	19.38	20.15	17.82	17.30	16.61	16.35	17.12	16.68	18.11	14.49	18.49	17.96	17.07
SUBSOILED 15 INCHES DEEP.															
1 foot	21.62	18.20	18.00	20.27	14.35	14.30	20.73	16.75	18.20	26.94	16.97	13.82	22.39	16.58	16.08
2 feet	22.40	20.80	19.70	21.23	18.60	20.25	21.02	19.68	19.66	21.50	20.30	19.60	21.54	19.85	19.80
3 feet	20.65	19.60	19.75	20.57	18.78	18.40	16.70	13.47	19.50	18.85	16.57	18.37	19.14	17.11	19.01
4 feet	20.20	19.15	19.55	19.63	17.70	17.60	15.93	18.38	17.98	17.51	17.58	15.91	18.32	18.20	17.76
5 feet	18.50	18.30	18.90	17.75	17.65	17.28	14.81	15.20	15.71	12.70	13.52	13.00	15.94	16.17	16.22
6 feet	19.90	21.35	20.25	20.15	19.65	18.90	18.20	19.11	19.22	18.25	19.01	16.11	19.13	19.78	18.62
Average	20.54	19.57	19.36	19.93	17.79	17.79	17.90	17.10	18.38	19.29	17.33	16.14	19.41	17.95	17.92
PLOWED 10 INCHES DEEP.															
1 foot	21.63	16.40	17.70	20.95	14.98	15.35	20.90	17.80	16.39	22.12	18.23	13.91	21.40	16.85	15.84
2 feet	22.45	21.05	20.00	21.97	18.70	20.45	18.20	20.83	20.03	21.90	19.83	18.63	21.13	20.10	19.78
3 feet	21.45	19.80	19.65	20.82	19.25	18.68	17.84	19.89	19.63	20.40	18.64	18.09	20.13	19.40	19.01
4 feet	20.35	18.85	18.40	19.92	17.80	17.88	14.46	17.15	18.45	14.67	15.38	15.72	17.35	17.30	17.61
5 feet	20.32	18.20	15.95	20.90	18.10	17.75	15.80	16.14	17.08	11.35	13.22	13.55	17.09	16.42	16.08
6 feet	20.67	20.60	18.90	21.52	18.88	18.88	17.99	18.43	17.27	12.70	16.51	15.59	18.22	18.61	17.66
Average	21.14	19.15	18.43	21.01	17.95	18.17	17.53	18.37	18.14	17.19	16.97	15.92	19.22	18.11	17.66
PLOWED 5 INCHES DEEP.															
1 foot	21.65	15.10	17.05	20.90	15.65	14.83	20.90	17.94	17.50	22.40	18.73	15.20	21.46	16.85	16.15
2 feet	21.85	20.40	18.70	21.30	19.98	19.88	21.38	20.54	19.55	24.07	19.40	20.48	22.15	20.08	19.65
3 feet	21.20	19.35	19.00	19.08	17.30	18.50	17.48	19.17	19.44	19.07	18.22	20.17	19.21	18.51	19.28
4 feet	20.30	18.50	18.60	18.23	16.68	18.13	13.12	17.26	17.59	14.25	16.29	18.15	16.33	17.18	18.12
5 feet	19.55	17.92	18.00	19.05	18.93	19.73	14.78	15.59	17.20	16.42	17.65	18.56	17.30	17.52	18.37
6 feet	20.00	18.95	19.70	16.35	15.93	15.50	15.23	16.59	17.19	16.20	15.65	14.75	16.95	16.78	16.79
Average	20.76	18.37	18.51	19.15	17.41	17.76	17.15	17.85	18.08	18.74	17.66	17.89	18.90	17.82	18.06

It will be seen from the above that during each year since 1908 four adjacent plats, each plowed to a different depth, have been fallow and that since 1909 these four plats, with four alternates, have been cropped or fallowed. This arrangement has afforded an opportunity each year to study soil moisture on the fallow plats and yields on the cropped plats, as influenced by shallow plowing, deep plowing, and subsoiling.

MOISTURE CONTENT OF FALLOW.

All of the fallow plats of each year were sampled at the beginning, in the middle, and at the end of the season. Samples were taken to

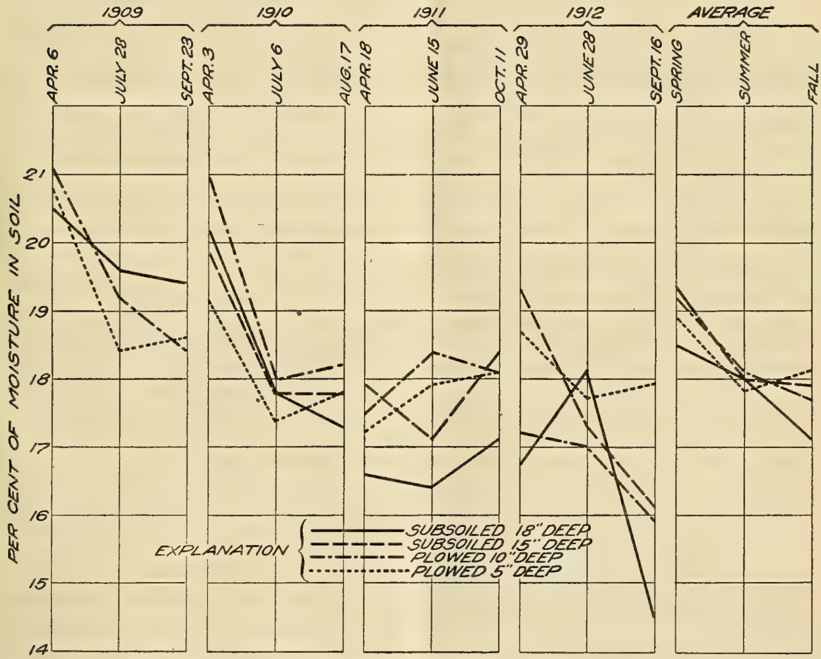

FIG. 5.—Graphs showing the average percentage of moisture in the first 6 feet of soil at the beginning, in the middle, and at the end of the fallow season, as found in the spring-plowing and fall-plowing tests at the Nephi substation, 1909 to 1912, inclusive.

a depth of 6 feet, and the moisture content of each foot section was determined separately. Table IV presents the data collected from 1909 to 1912, inclusive, and shows the annual and average percentage of moisture in each foot section of soil and the average of the 6-foot section in April, June, and September.

The data presented in Table IV show (1) that there was very little difference in the soil-moisture content of these plats in the spring, summer, or fall; (2) that all of the plats uniformly lost much of the moisture of the first foot during the spring cultivation necessary to rid the plats of weeds and volunteer grain and to prepare them for the fallow season; (3) that the moisture below the first foot remained

practically the same on all plats during the fallow season; and (4) that the average percentage of moisture in the fall was lower for the plats subsoiled to a depth of 18 inches than for any of the other plats. These facts are shown graphically in figures 5, 6, and 7.

The points thus brought out show that, so far as soil moisture is concerned, there was no advantage in deep plowing or subsoiling, for the moisture content of the plat plowed 5 inches deep (shallow plowing) was as high as that of any of the others. So far as the preparation of a seed bed is concerned, however, it was found that in most cases the shallow plowing was less desirable because the stubble was not turned under as well as by the deeper plowing. Because of this the surface of the shallow-plowed plat usually contained much trash,

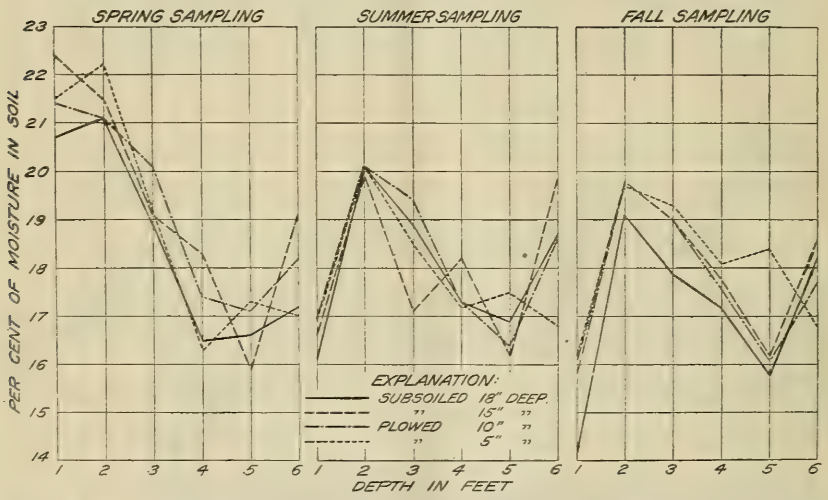

FIG. 6.—Graphs comparing the average percentage of moisture in each of the upper 6 feet of soil at the beginning, in the middle, and at the end of the fallow season, as found in the fall depth-of-plowing tests at the Nephi substation, 1909 to 1912, inclusive.

which interfered somewhat with the operation of the drill when the plat was seeded.

YIELD OF GRAIN.

The annual and average yields of the plats in these tests are presented in Table V and are shown graphically in figure 8.

TABLE V.—*Annual and average yields of winter wheat on plats used in the depth-of-plowing tests at the Nephi substation, 1910 to 1913, inclusive.*

Treatment.	Yield per acre of grain (bushels).				
	1910	1911	1912	1913	Average.
Subsoiled 18 inches deep	14	28	18	4	16.0
Subsoiled 15 inches deep	13	29	19	6	16.7
Plowed 10 inches deep	13	29	21	7	17.5
Plowed 5 inches deep	12	27	20	10	17.2

The yields obtained in this test, as shown in Table V, agree with the moisture content of the plats, as previously discussed. The highest average yield was obtained from the plats plowed 10 inches deep, and the lowest average yield was obtained from the plats subsoiled 18 inches deep, while the plats plowed 5 inches deep gave better yields than those subsoiled 15 inches deep. The widest difference in the yields, however, is not significant. The point most strongly emphasized by the results is that there was no material difference in the yields obtained from plats plowed at depths varying from 5 to 18 inches.

RELATIVE COST OF PLOWING AND SUBSOILING.

Since there was no material difference in the moisture content or in the yields of the plats included in the depth-of-plowing tests, it is

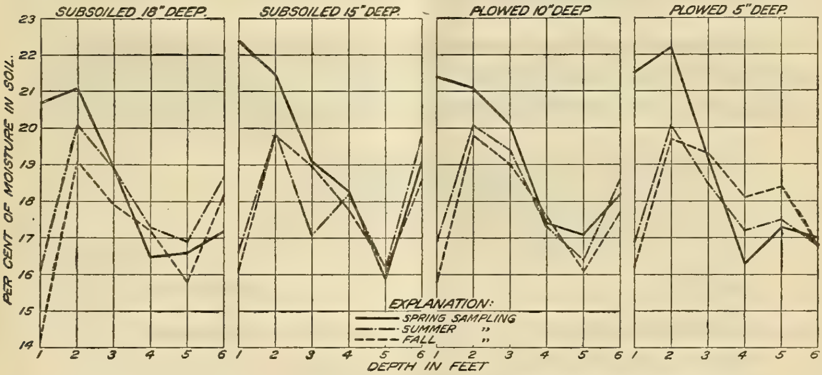

FIG. 7.—Graphs showing the average seasonal decline in percentage of moisture in each of the upper 6 feet of soil, as found in the fall depth-of-plowing tests at the Nephi substation, 1909 to 1913, inclusive.

well to consider the cost of crop production on the plats to determine, if possible, the comparative value of each operation. The subsoiled plats were first plowed and then subsoiled, the subsoiler following in the plow furrow. The draft of the subsoiler was as great as that of the plow; hence, the subsoiling entailed twice the expense of plowing and did not increase the yield of the plat. For this reason there was nothing in favor of and much against subsoiling as tested at Nephi.

There was so little difference between the yields of the two plowed plats that it is difficult to see any advantage in favor of deep plowing over shallow plowing. In fact, when considered from the standpoint of net returns, there was no advantage for deep plowing, because of the greater expense incurred. The most evident point in favor of deep plowing seems to be, as previously noted, that it covers the stubble better and this obviates some trouble at seeding time. Had some plats been plowed at different depths between 5 and 10 inches and some others plowed at these same depths in the spring as well as in the fall, it is possible that some more significant data

would have been obtained. With the data available, however, the question seems to be not so much how deep to plow as how well to plow.

Depth of Fall and Spring Plowing.

As already stated, there is always need in the spring of replowing or double disking land that has been plowed the previous fall. Because of this condition, an experiment was commenced in 1911 to determine whether it is best to plow deep in the fall and then shallow in the spring, or vice versa. In this test, plats 24C and 25C have been used alternately with plats 25A and 26A. One plat was plowed

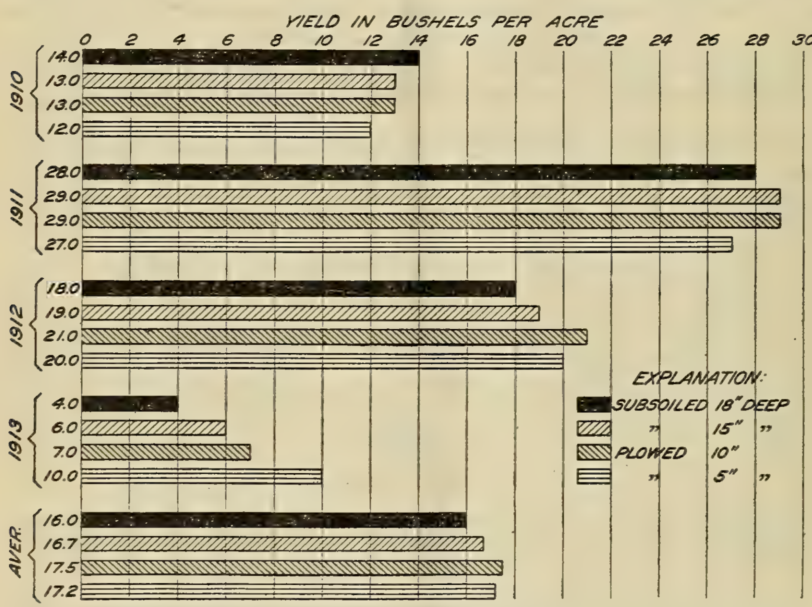

Fig. 8.—Diagram comparing the annual and average yields obtained in the fall depth-of-plowing tests at the Nephi substation, 1910 to 1913, inclusive.

only 3 inches deep in the fall, while the other was plowed 8 inches deep at the same time. The following spring the plat which was fall plowed 3 inches deep was replowed 8 inches deep, while the other plat was replowed only 3 inches deep. These plats were compared with an adjacent plat treated according to general practice in the region.

The soil-moisture determinations made in 1912 show no difference between the two methods. The yields of 1913, however, slightly favor the plat plowed 8 inches deep in the fall and 3 inches deep in the spring, but the difference is not significant. The test must be continued for several years before the results will be of value.

CULTIVATION OF FALLOW.

The purpose of the experiments in cultivating fallow land has been to determine the value of cultivation as compared with no cultivation. Very little has been done to determine the relative value of such factors as depth, method, and frequency of cultivation, etc., further than to observe and to note differences whenever they were apparent. These factors are so variable, however, that the notes made do not suggest any established principles.

Cultivation of Fall-Plowed Fallow.

Since 1908 two pairs of plats, alternately cropped and fallowed, have been used at Nephi in an endeavor to determine the value of cultivation as compared with no cultivation of fall-plowed fallow. Two adjacent plats were plowed uniformly in the fall of each year, and both were allowed to lie in a rough condition through the following winter. During the next spring and summer one of these plats received normal cultivation, while the other was not cultivated. Both were seeded uniformly in the fall and the further treatment of the plats was identical. These two plats alternated with two other plats which received the same treatment.

The cultivated fallow plat was replowed or double disked in the spring after fall plowing, to destroy weeds and volunteer grain. It was then harrowed, and during the succeeding summer it was harrowed and weeded as often as necessary. At least three harrowings were given the plat—one in the spring, one in the summer, and another just prior to the time of seeding; and the plat was weeded once or twice. On the other plat, weeds and volunteer grain were allowed to grow, but all growth was clipped before it matured, in order to minimize subsequent weed trouble.

MOISTURE CONTENT OF FALLOW.

Soil samples were taken from the fallow plats at the beginning, in the middle, and at the end of the season. Six-foot borings were made and the moisture content of each foot section was determined in the usual manner. The data obtained from these determinations are presented in Table VI, which shows the annual and average percentages of moisture in each foot and the average percentages in the 6 feet in the spring, in the summer, and in the fall for both the cultivated and the uncultivated fallow for the four years 1909 to 1912, inclusive.

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TABLE VI.—*Annual and average percentages of moisture in each of the first 6 feet of soil on cultivated and uncultivated fallow at the Nephi substation, samples taken in spring, summer, and fall, for the years 1909 to 1912, inclusive.*

FALLOW CULTIVATED NORMALLY.

Depth of sampling.	Date of determination.														
	1909			1910			1911			1912			Average.		
	Apr. 21.	June 15.	Sept. 18.	Apr. 15.	June 24.	Sept. 6.	Apr. 18.	June 12.	Sept. 21.	Apr. 25.	June 26.	Sept. 16.	Spring.	Summer.	Fall.
1 foot	19.22	16.35	17.15	14.50	16.05	13.53	18.82	17.39	12.52	21.67	14.07	14.47	18.55	15.97	14.42
2 feet	19.60	19.65	16.55	18.20	18.80	19.35	19.69	19.53	17.74	22.06	19.87	18.88	19.89	19.46	18.13
3 feet	19.50	19.50	18.85	18.95	17.85	18.03	18.65	19.63	17.72	20.05	18.47	17.85	19.29	18.86	18.11
4 feet	19.40	18.90	18.70	19.33	19.63	18.68	14.95	18.80	16.56	13.32	14.20	14.10	16.75	17.88	17.01
5 feet	18.20	18.00	18.05	19.05	18.33	19.15	13.41	20.80	15.31	10.44	10.95	12.53	15.28	17.02	16.26
6 feet	20.00	20.30	19.35	19.30	18.80	18.45	17.44	17.60	17.89	15.85	13.92	13.54	18.15	17.66	17.31
Average	19.32	18.78	18.11	18.22	18.24	17.86	17.16	18.96	16.29	17.23	15.25	15.23	17.98	17.81	16.87

FALLOW NOT CULTIVATED.

1 foot	18.60	12.65	12.30	12.85	10.45	8.05	20.00	12.83	9.61	20.47	10.68	7.95	17.98	11.65	9.32
2 feet	19.30	15.80	13.20	17.37	14.05	12.23	20.16	14.99	12.98	20.75	12.36	11.46	19.30	14.30	12.47
3 feet	20.45	16.55	14.15	19.10	13.28	11.78	17.88	17.08	12.28	17.21	12.91	11.18	18.66	14.96	12.35
4 feet	19.35	17.55	15.25	18.93	13.80	10.38	12.03	14.89	11.61	10.83	11.35	10.74	15.29	14.40	12.00
5 feet	19.05	18.15	16.15	19.35	16.18	13.45	11.10	13.94	11.20	11.27	14.47	11.86	15.19	15.69	13.17
6 feet	20.57	20.42	18.95	19.10	16.63	15.33	13.10	18.11	12.06	14.17	15.76	12.27	16.74	17.73	14.65
Average	19.55	16.85	15.00	17.79	14.06	11.87	15.71	15.31	11.62	15.78	12.92	10.91	17.20	14.79	12.34

Table VI shows that the moisture content of the plats was practically uniform in the spring, but that the differences increased as the season advanced. The moisture in the cultivated plat remained practically the same throughout the season, while that of the uncultivated plat rapidly decreased until by fall it was reduced to a comparatively low point. The first 4 feet seemed to lose more moisture than the fifth and sixth. These data are shown graphically in figures 9, 10, and 11. The fact that the moisture content of the second, third, and fourth feet of the uncultivated plat was reduced practically as much as on any of the cropped plats sampled suggests that a great deal of the moisture loss from the uncultivated plat was due to the growth of weeds and volunteer grain.

YIELD OF GRAIN.

The difference in the soil-moisture content of the plats, as shown in Table VI and figures 9, 10, and 11, is reflected in the yields obtained. These are reported in Table VII and are compared graphically in figure 12. It will be noticed that there is a difference of 4 bushels per acre in the average yield for the four years in favor of the cultivated plats. This difference is more than enough to pay for the cultivation of the fallow.

TABLE VII.—*Annual and average yields of winter wheat on cultivated and uncultivated fallow at the Nephi substation, for the years 1910 to 1913, inclusive.*

Treatment.	Yield per acre of grain (bushels).				
	1910	1911	1912	1913	Average.
Fallow cultivated	13	29	21	5	17
Fallow not cultivated	14	18	15	5	13

CULTIVATION OF SPRING-PLOWED FALLOW.

In the spring of 1912 tests similar to the ones last discussed were begun on spring-plowed fallow. Both plats produced winter wheat

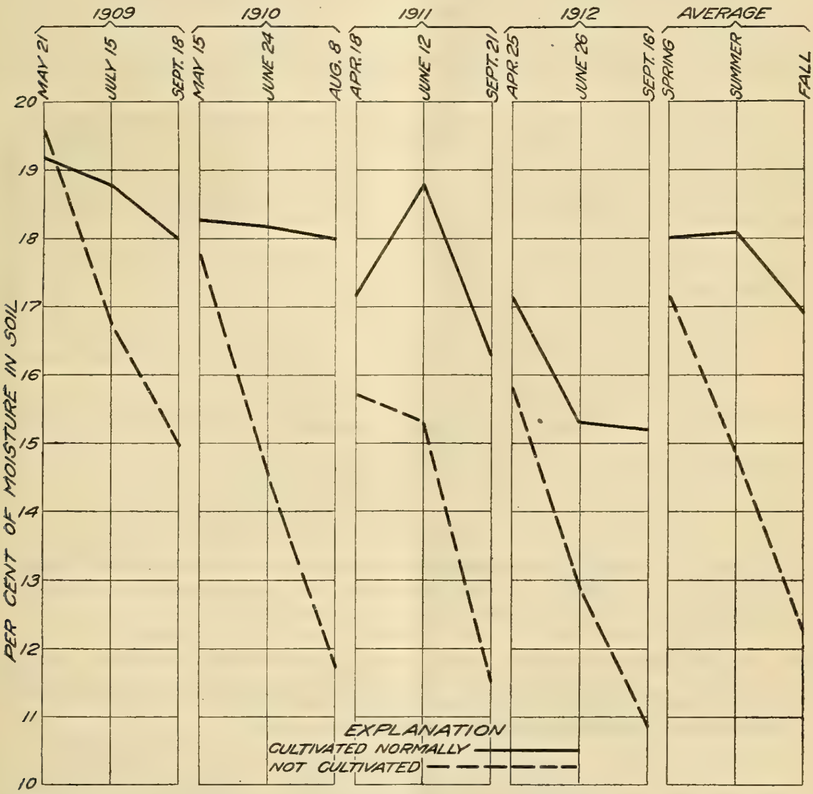

FIG. 9.—Graphs showing the average percentage of moisture in the first 6 feet of soil at the beginning, in the middle, and at the end of the fallow season, as found in the summer-cultivation tests of fall-plowed fallow at the Nephi substation, 1909 to 1912, inclusive.

in 1911 and were left in stubble during the winter. They were plowed uniformly as soon as possible the next spring. One was then cultivated normally during the summer of 1912, while the other was not cultivated. There were practically no weeds or volunteer grain on

either plat, but whatever growth appeared on the cultivated plat was destroyed, while on the uncultivated plat it was allowed to remain but not to mature. Both plats were seeded uniformly in the fall of 1912 and they were treated alike during 1913. Two alternate plats were added to the test in 1912.

Soil samples were taken from the fallow plats, and moisture determinations were made. These showed no appreciable difference in the moisture content of the plats in either the individual foot sections or the 6-foot averages. There was a uniform decline in the moisture content of the plats from spring to seeding time in the fall. The

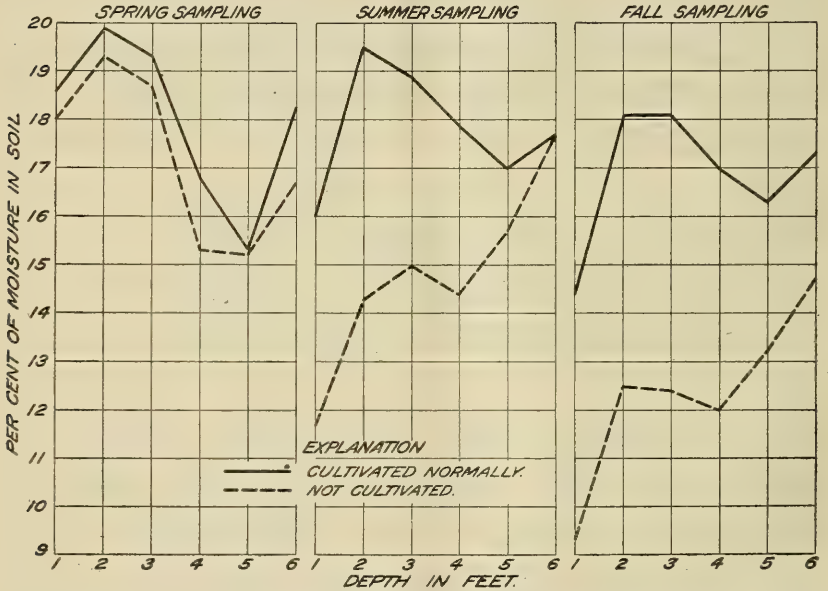

FIG. 10.—Graphs comparing the average percentage of moisture in each of the upper 6 feet of soil at the beginning, in the middle, and at the end of the fallow season, as found in the summer-cultivation tests of fall-plowed fallow at the Nephi substation, 1909 to 1912, inclusive.

yield of the plats in 1913, 11.9 and 9.5 bushels per acre, slightly favored the noncultivated plat, but there was so much winterkilling on both that the yields are not significant.

The value of these tests was increased in 1912 by the addition of nine other plats, treated as follows: Two plats, light cultivation; two plats, medium cultivation; two plats, heavy cultivation; and three plats, no cultivation.

These nine plats will be kept free from all vegetative growth. The noncultivated plats will be weeded with the least possible disturbance of the soil, thus affording an opportunity to study the value of cultivation methods for moisture conservation alone and not in connection with weed eradication.

SEEDING WINTER CEREALS.

Four important factors related to the seeding of winter cereals, namely, the time, depth, method, and rate of seeding, have been rather extensively considered in the experimental work of the Nephi substation since its beginning. All these factors are interrelated and are so regarded in ordinary farm practice, but at Nephi each has been

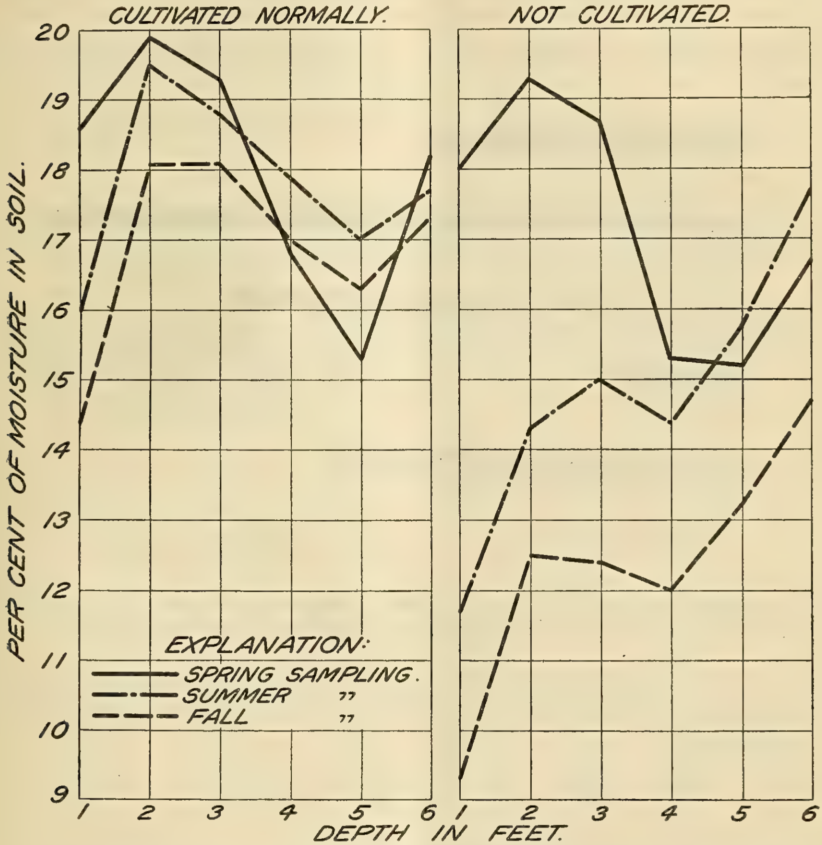

FIG. 11.—Graphs showing the average seasonal decline in percentage of moisture in each of the upper 6 feet of soil, as found in the summer-cultivation tests of fall-plowed fallow at the Nephi substation, 1909 to 1912, inclusive.

considered apart from the others arbitrarily, and the results are so presented herein.

TIME OF SEEDING WINTER CEREALS.

WHEAT.

The experiments dealing with the time of seeding winter wheat have been in progress since 1903. During that time winter wheat has been sown each year at a uniform rate of 3 pecks to the acre on

each of the following dates: August 15, September 1, September 15, October 1, October 15, and November 1. In the years from 1904 to 1907, inclusive, the variety used was the Odessa (C. I. No. 3274). This variety was replaced by the Koffoid (C. I. No. 2997) in 1908 and 1909. From 1910 to 1913 both the Koffoid and the Turkey (C. I. No. 2998) have been used. Table VIII shows the average yields for the 6 years from 1904 to 1909, inclusive; the annual and average yields for both varieties for the 4 years from 1910 to 1913, inclusive; and the average yields for the entire 10-year period for

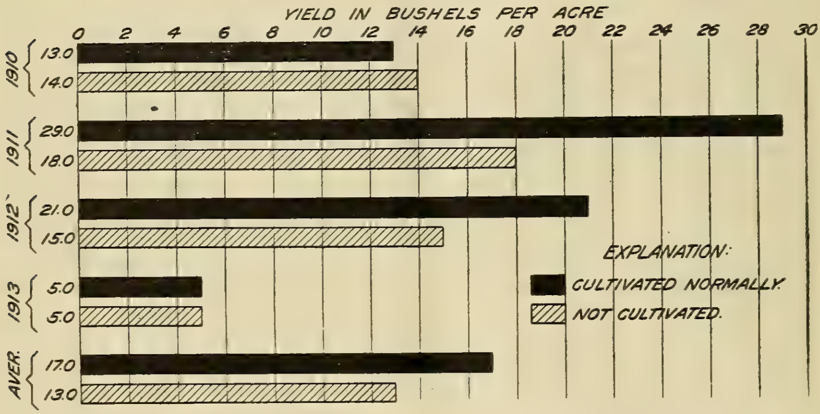

FIG. 12.—Diagram comparing the annual and average yields obtained in the summer-cultivation tests of fall-plowed fallow at the Nephi substation, 1910 to 1913, inclusive.

each of the six dates upon which the grain was sown. The average yields for the 10-year period are presented graphically in figure 13.

TABLE VIII.—*Annual and average yields of two varieties of winter wheat for the years 1910 to 1913, showing also the average yields of one variety for the years 1904 to 1909, and of all varieties for the years 1904 to 1913, inclusive, in date-of-seeding tests at the Nephi substation.*

Date seeded.	Yield per acre of grain (bushels).											
	Annual yields.								Average yields.			
	1910		1911		1912		1913		1910–1913		1904–1909,[1] one variety.	1904–1913, all varieties.
	Koffoid.	Turkey.	Koffoid.	Turkey.	Koffoid.	Turkey.	Koffoid.	Turkey.	Koffoid.	Turkey.		
Aug. 15	15.60	27.30	21.70	23.50	13.50	13.40	Failure.	1.70	12.70	16.48	17.95	16.61
Sept. 1	32.20	36.80	17.80	28.60	6.30	5.30	0.67	6.83	14.24	19.38	20.32	18.92
Sept. 15	12.20	20.80	33.80	36.50	9.40	7.70	2.67	10.83	14.52	18.96	15.99	16.29
Oct. 1	9.50	13.50	29.90	26.40	17.80	15.90	3.00	10.67	15.05	16.62	22.00	19.53
Oct. 15	11.70	16.00	22.50	6.00	15.70	7.30	1.17	8.83	12.77	9.53	22.68	18.07
Nov. 1	14.20	17.80	9.20	10.00	4.20	7.30	(2)	(2)	9.20	11.70	20.46	17.12

[1] The average yields for the six years from 1904 to 1909 presented here were taken from Circular 61, Bureau of Plant Industry, U. S. Department of Agriculture, in which they were presented in connection with the annual yields for the same period.
[2] Not sown, because of stormy weather.

The results presented in Table VIII show no correlation between time of seeding and yield. Early seeding has given the best results in some years, while in others the best yields have come from late seeding, especially those in October. It will be observed, however, that as a rule the best yields have come from seeding between September 1 and October 15.

SOIL MOISTURE AT SEEDING TIME.

Beginning in the fall of 1908, the plats used in the time-of-seeding test were sampled to a depth of 6 feet just prior to the seeding of the plats. In the later years, when two varieties were sown, composite samples of both plats were taken. The percentages of moisture in

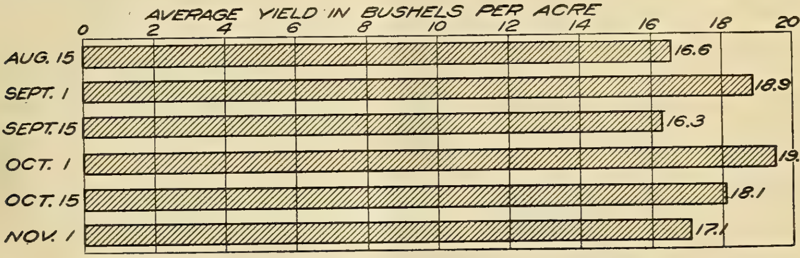

FIG. 13.—Diagram comparing the 10-year average yields of winter wheat obtained in the time-of-seeding tests at the Nephi substation, 1904 to 1913, inclusive.

each foot of soil at seeding time as shown by these samples are given in Table IX.

TABLE IX.—*Annual and average percentages of moisture in each of the first 6 feet of soil at different dates of seeding at the Nephi substation, for the years 1908 to 1912, inclusive.*

Date of seeding.	Depth of sampling.	1908 [1]	1909	1910	1911	1912	Average.
Aug. 15	1	16.40	14.60	12.85	12.67	13.65	14.03
	2	17.30	19.05	17.44	15.55	17.75	17.42
	3	14.12	17.10	16.12	10.87	14.48	14.54
	4	12.45	18.30	17.33	10.84	12.40	14.26
	5	12.95	20.60	18.25	12.24	9.88	14.78
	6	12.37	18.15	17.20	14.48	11.60	14.76
Average		14.26	17.96	16.53	12.78	13.29	14.96
Sept. 1	1	15.95	17.30	14.73	11.60	15.65	15.05
	2	18.10	18.30	17.33	15.04	18.83	17.52
	3	15.35	17.75	16.28	11.80	15.87	15.41
	4	10.70	19.45	17.05	10.75	12.03	14.00
	5	9.75	17.75	16.50	8.01	10.60	12.52
	6	10.82	18.30	19.15	9.08	13.12	14.09
Average		13.44	18.14	16.84	11.05	14.35	14.76
Sept. 15	1	16.32	17.45	12.10	9.97	11.91	13.55
	2	16.70	18.75	17.38	12.53	16.69	16.41
	3	14.92	17.00	16.53	11.20	15.24	14.98
	4	10.22	17.55	17.45	12.44	13.09	14.15
	5	10.57	16.85	16.22	11.93	9.23	12.96
	6	11.45	17.40	17.65	11.00	10.61	13.62
Average		13.36	17.50	16.22	11.51	12.80	14.28

[1] One plat only. In each of the other years the figures given are the average of two plats.

TABLE IX.—*Annual and average percentages of moisture in each of the first 6 feet of soil at different dates of seeding at the Nephi substation, for the years 1908 to 1912, inclusive*—Continued.

Date of seeding.	Depth of sampling.	1908 [1]	1909	1910	1911	1912	Average.
Oct. 1	1	20.00	15.60	12.88	13.47	12.55	14.90
	2	19.40	18.90	16.43	16.07	17.00	17.56
	3	15.55	16.00	16.58	14.98	14.49	15.52
	4	11.27	17.90	16.78	15.24	13.17	14.87
	5	10.77	16.70	18.38	14.34	13.57	14.75
	6	12.72	17.05	16.33	14.23	13.37	14.74
Average		14.95	17.02	16.23	14.72	14.03	15.39
Oct. 15	1	16.90	15.35	14.61	12.29	17.87	15.40
	2	18.60	17.75	16.80	14.98	18.59	17.34
	3	15.35	16.55	16.65	14.63	17.40	16.12
	4	14.10	16.05	16.33	13.57	15.92	15.19
	5	11.08	16.65	16.28	11.95	13.75	13.94
	6	10.92	17.75	18.00	13.14	15.45	15.05
Average		14.49	16.68	16.44	13.44	16.50	15.51
Nov. 1	1	18.55	13.95	17.85	14.68	(2)	16.26
	2	20.52	17.35	18.78	18.02		18.67
	3	19.72	16.20	18.30	14.60		17.21
	4	13.90	13.95	17.63	11.25		14.18
	5	11.15	14.15	17.05	8.97		12.83
	6	10.37	14.50	16.55	15.49		14.23
Average		15.70	15.02	17.69	13.84		15.56

[1] One plat only. In each of the other years the figures given are the average of two plats.
[2] Stormy weather prevented the sampling and seeding of these plats.

It will be noticed in Table IX that there was no great difference in the average moisture content of the plats. The surface foot, usually very dry in the first few inches, varied in moisture content to some extent, owing partly to rainfall, but even in this foot the variation is within the limits of experimental error. Moisture in the first foot of soil is of chief importance at seeding time, because it is here that the plant starts life, and for this reason some relation between the moisture content of the first foot of soil at seeding time and the yield of the crop might be expected. This relation failed to appear, however, in any one year. That it was not apparent in an average for the four years from 1909 to 1912 is shown in figure 14, in which the average moisture content of the first foot of soil on the six different dates of seeding, and the average yields of two varieties of winter wheat seeded on those dates are graphically presented.

Figure 14 shows an apparent relationship between the moisture content of the first foot of soil and the yields of the plats seeded on the two earlier dates, but for later dates the curves run almost parallel to each other. A discussion of the physical factors influencing the time of seeding will aid in explaining this condition.

FACTORS INFLUENCING THE TIME OF SEEDING.

On the dry lands of the Great Basin the best time for seeding winter wheat is greatly limited by climatic conditions. The long, dry summers exhaust the moisture of the fallow soil nearly to the depth to which the land is plowed, leaving the surface soil almost

dusty to a depth of 4 to 8 inches. This condition, combined with continued lack of rainfall, often prevents the sowing of wheat until very late in the fall, sometimes until farmers are compelled to sow in order to have the seed in the ground before snow falls. It is impracticable to sow seed in the dry soil, because it would not germinate until rain fell, and then, if the storms brought insufficient moisture for continued growth, the plant very likely would die after sprouting. This makes early seeding in dry soil precarious. Farmers, realizing this fact, seldom seed "in the dust," although good yields have sometimes been obtained from such seeding when it is followed by sufficient moisture for germination and continued growth.

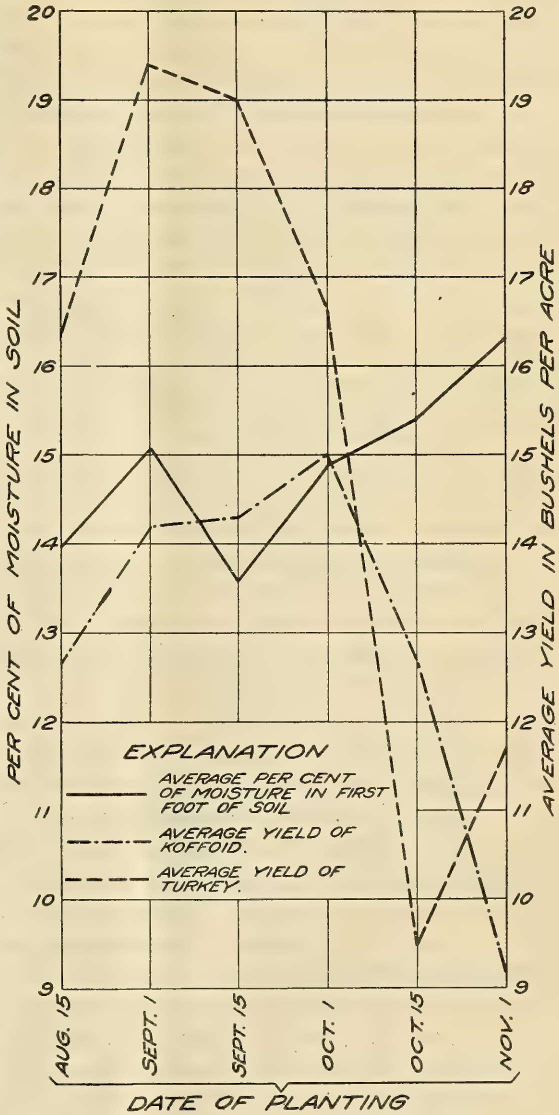

FIG. 14.—Graph showing the average percentage of moisture in the first foot of soil at seeding time in the fall and the average yields of two varieties of winter wheat used in the time-of-seeding tests at the Nephi substation, 1909 to 1913, inclusive.

It is almost impossible to place the seed below the dry soil, and, if it were possible, it is not practicable, because small seeds placed so deep often have difficulty in getting their first leaves to the surface. These facts explain why farmers generally wait for rain to wet the surface soil before they sow their wheat. In order to obtain the highest yields from winter wheat in the Great Basin, however, it is essential that the plants make at least a fair growth before winter begins. To get the desired growth, the seed should be sown

not later than October 1. When seeding is delayed until very late in the fall there is great danger of injury to the young plants if germination occurs, from what may be termed "fall killing." They are in a very critical condition when freezing weather arrives. An open winter following this injury results in almost total failure of the crop, regardless of the tillage methods used in preparing the land and of the amount of moisture stored in it.

As practical examples of the points brought out in the preceding discussion, the past four seasons, 1909–10 to 1912–13, are worthy of consideration. The seedings on August 15 and September 1, 1909, were made when, owing to recent rains, there was plenty of moisture in the first foot to cause good growth. The yields of these plats in 1910 were high in comparison with those of the plats sown later, when the weather was dry and cold. The seedings on September 15, 1910, were made under conditions similar to those in August, 1909. The yields on these plats were higher than those seeded "in the dust" in August and those sown late in October. In the fall of 1911 and again in 1912 the weather was dry until early October, after which time there was plenty of moisture, but the weather was cold. As a result of these conditions the yields of both early-sown and late-sown crops were low. Figure 15 shows the relation of precipitation to yield in this instance. The blackened portions of the figure illustrate the daily precipitation from August 1 to November 30, inclusive, and the curves represent the yields in bushels per acre of the two varieties of wheat seeded on different dates during these months.

It will be seen that early seeding if done in wet weather gave high yields, while it gave low yields, and sometimes almost failures, when done in dry weather. It is also shown that late seeding, even when there was plenty of moisture, often resulted in serious loss because of injury to the tender plants by freezing. There seems to have been some difference in the effect of these climatic conditions on the two varieties. This may have been due to a difference in the time of germination between the hard (Turkey) variety and the soft (Koffoid) variety. The writer is of the opinion that this difference in germination is largely responsible for the differences in yield. The soft wheat seems to germinate more rapidly than the hard wheat, and for this reason it is more advanced on a given date than the latter variety. This may not always be advantageous to it, as it may be in a tender stage of growth when drought or cold weather strikes it, and thus it may be injured more than the ungerminated seed of the hard variety. On the other hand, the soft wheat may be sufficiently far advanced to protect it from injury, while the slower germinating Turkey wheat may be still in a tender stage of growth.

The climatic and soil conditions under which these results were

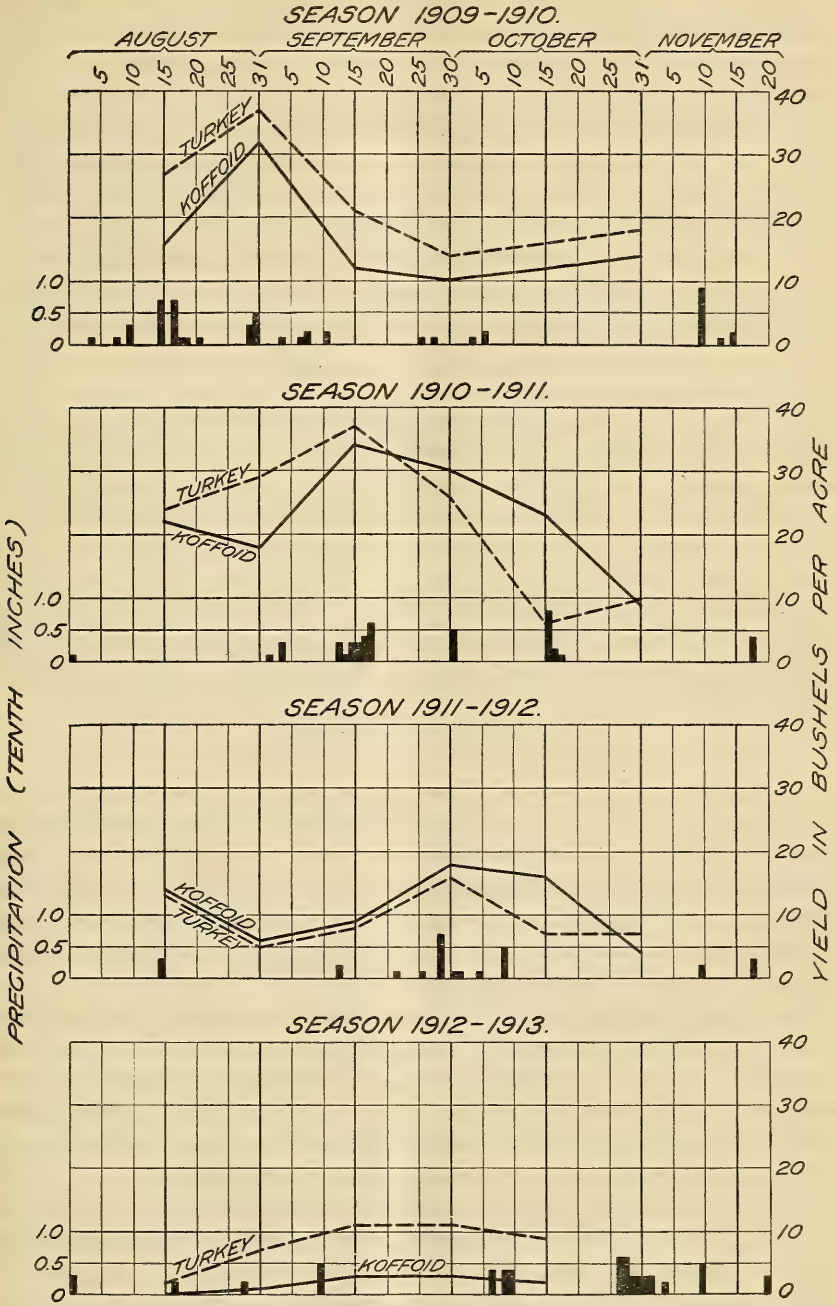

FIG. 15.—Diagrams showing the precipitation at seeding time in the fall and curves showing the annual yields of two varieties of winter wheat used in the time-of-seeding tests at the Nephi substation, 1909 to 1913, inclusive.

obtained present problems of a different nature than those so far

studied. Early seeding, not later than October 1, seems desirable, but as this is not always practicable, owing to a dry seed bed, the chief problem seems to be a mechanical one involving some improvement of the machinery now used in seeding the grain. The improvement believed to be necessary comprises a means for opening a furrow through the dry surface soil, sowing the seed in moist earth at the bottom of the furrow, and leaving the furrow partly open so that the plants will not have to force their way through several inches of dry soil. It is believed that seed could be sown with good results in dry weather by this method, as the seed would germinate rapidly and a good stand of grain would be established before winter, thus greatly increasing the possibilities of a good crop.

BARLEY, OATS, AND EMMER.

In the fall of 1911 date-of-seeding tests with winter barley, winter oats, and winter emmer were begun. Four dates were used for each grain, namely, September 1, September 15, October 1, and October 15. All grains were sown at the rate of 6 pecks per acre on the "oats" side of the drill. As has already been explained in connection with the discussion of the time of seeding winter wheat, there was much winterkilling in the seasons of 1911–12 and 1912–13, and, consequently, the results obtained from these experiments with barley, oats, and emmer are of little value. The tests are being continued, however.

Depth of Seeding Winter Cereals.

Depth-of-seeding tests with winter wheat have been in progress since the fall of 1908, while similar tests with winter barley, winter oats, and winter emmer were begun in 1911. In all the tests, seed has been sown at three different depths, 1.5, 3, and 6 inches, the drill being set in the first, second, or third notch, according to the depth desired. In all respects other than depth of seeding, the plats in each test were treated uniformly.

Each fall the plats were seeded at what was considered the best time. Sometimes, as in 1909 and 1910, it was possible to sow the seed early enough to obtain a fair growth before winter and, as a result, good yields were obtained. On the other hand, as in 1908, 1911, and 1912, seeding was not possible until very late in the season, resulting in poor yields, for reasons already explained.

The yields of winter barley, oats, and emmer were so small in 1912 and 1913, because of late seeding and subsequent freezing, that they are not dependable and need not be presented here. The yields of winter wheat in 1913 also were very small, but as they are important in connection with the results of the preceding four years, the yields for the five years are presented in Table X. .

TABLE X.—*Annual and average yields of winter wheat sown at different depths at the Nephi substation, for the years 1909 to 1913, inclusive.*[1]

Depth planted.	Yield per acre of grain (bushels).					
	1909	1910	1911	1912	1913	Average.
About 1.5 inches (drill in first notch)	4.30	20.20	27.70	16.30	3.20	14.34
About 3 inches (drill in second notch)	[2] 4.07	16.60	28.50	16.30	2	13.49
About 6 inches (drill in third notch)	2.10	15	27.20	19.10	2	13.08

[1] The Koffoid variety (C. I. No. 2997) was used in 1909, while Turkey (C. I. No. 2998) was used from 1910 to 1913, inclusive.
[2] Average yield of seven check plats.

The results of five years as recorded in Table X show very little difference in the average yield of winter wheat seeded at different depths. The yields of 1910, a good season, favored shallow seeding. Those of 1911, a better season, showed a slight advantage in favor of a medium depth of seeding. In fact, it seems that depth of seeding is less important than time of seeding, which, as has been shown, is governed at present by soil and climatic conditions.

METHOD OF SEEDING WINTER WHEAT.

Tests designed to determine the relative value of broadcasting, ordinary drilling, and cross drilling have been carried on at Nephi for several years. After what has been said concerning the soil and climatic conditions which usually obtain at seeding time in the fall, it is easy to see why broadcasting has been not nearly so successful as drilling. The broadcast plats have been practically failures each season that method of seeding has been tested, while the drilled plats yielded from 20 to 25 bushels per acre.

On the cross-drilled plats the drill was first drawn lengthwise and then crosswise of the plat. On one plat the usual rate of seeding, 3 pecks per acre, was used, while on the other twice the usual rate, or 6 pecks per acre, was used. In the one case the drill was set to sow at the rate of 1.5 pecks to the acre and in the other at the rate of 3 pecks, the cross drilling making the quantities sown double those just mentioned. Near these two plats there was always one seeded in the usual manner at 3 pecks per acre. This plat, being usually a check plat, was not always seeded at the same time as the others, however, and so its yields are not strictly comparable with those of the cross-drilled plats. All are presented, however, in Table XI, which gives the annual and average yields for the five years from 1909 to 1913, inclusive.

TABLE XI.—*Annual and average yields of winter wheat drilled in the ordinary manner and cross drilled at the Nephi substation, for the years 1909 to 1913, inclusive.*[1]

Method and rate of drilling.	Yield per acre of grain (bushels).						
	1909	1910	1911	1912	1913	Average.	
						5 years.	4 years.
Ordinary drilling at 3 pecks per acre	[2] 4.07	16.60	22.30	16.30	5.17	12.89	15.09
Cross drilling, 1.5 pecks per acre each way	3.50	18.50	26.70	17.10	6.00	14.36	17.08
Cross drilling, 3 pecks per acre each way	....	17.80	28.80	17.60	5.34	....	17.39

[1] The Koffoid variety was used in 1909, while the Turkey was used from 1910 to 1913, inclusive.
[2] Average of seven check plats.

Table XI shows that the difference between the yields of the cross-drilled plats and those drilled in the ordinary manner, both seeded at the rate of 3 pecks per acre, is very small, almost insignificant when the comparative cost of seeding is considered. It is not known whether the difference in yield favoring the cross-drilled plats is caused by cross drilling or by a possible increase in the rate of seeding which may have occurred owing to the double seeding, i. e., the drill may have seeded more than 3 pecks when set to sow 1.5 pecks each way of the plat. It is believed that the increase in the rate of seeding is responsible for the higher yield of the plats seeded at 6 pecks per acre, since these results agree with those of the rate-of-seeding tests with winter wheat.

RATE OF SEEDING WINTER WHEAT.

Rate-of-seeding tests with winter wheat were conducted at Nephi for the three years from 1909 to 1911, inclusive, and they were repeated in 1913. There was no test of this kind in 1912. In each year six different rates of seeding were used, namely, 2, 2.5, 3, 4, 5, and 6 pecks per acre. All plats in the test were treated uniformly in every way except as to the rate of seeding. The annual and average yields in bushels per acre obtained are presented in Table XII.

TABLE XII.—*Annual and average yields of winter wheat in the rate-of-seeding test at the Nephi substation in 1909, 1910, 1911, and 1913.*[1]

Rate of seeding per acre.	Yield per acre of grain (bushels).					
	1909	1910	1911	1913	Average.	
					4 years.	3 years (1910, 1911, and 1913).
2 pecks	4.16	16.00	23.50	Failure.	10.92	13.17
2.5 pecks	....	15.30	28.50	Failure.	....	14.60
3 pecks (ordinary)	....	19.30	21.30	2.67	....	14.42
4 pecks	7.75	19.30	28.70	3.00	14.69	17.00
5 pecks	4.80	19.30	33.70	2.83	15.16	18.61
6 pecks	2.33	17.00	30.30	3.00	13.16	16.77

[1] The Koffoid variety was used in 1909, while the Turkey was used in 1910, 1911, and 1913.

The principal fact brought out by Table XII is that the higher rates of seeding have given the largest average yields. This is rather contrary to the belief of dry-land farmers in the Great Basin, who fear that heavier seeding than 3 pecks to the acre would be disastrous to the crop in extremely dry seasons. That this view is not well founded is shown by the fact that in 1910 and 1911, the two driest years at Nephi since 1898, the highest rates of seeding gave yields as high as, or much higher than, the lower rates. The results available indicate that a 4-peck or 5-peck rate is the most profitable.

It is likely that 3 pecks per acre would be sufficient if all seeds sown produced plants that matured, but it has been found at Nephi that the average winter survival among fall-sown cereals is about 65 per cent,[1] in which case only about 30 pounds of the seed produce plants that mature.

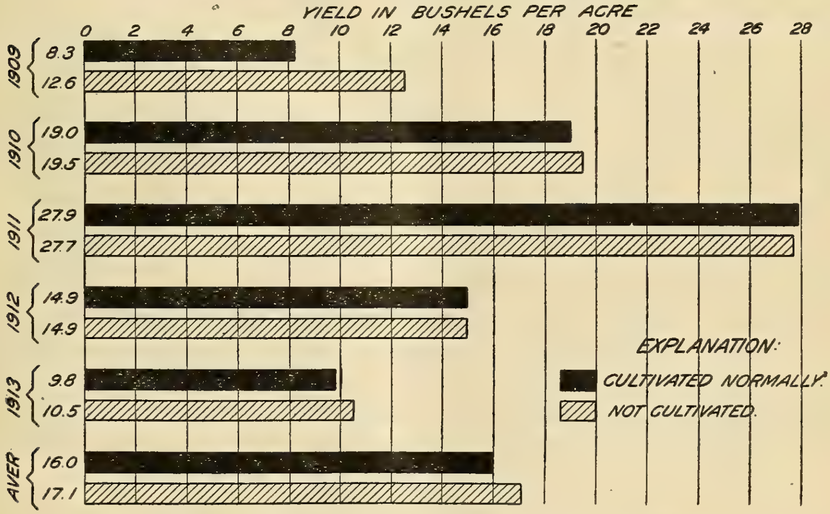

FIG. 16.—Diagram comparing the annual and average yields obtained in the spring-cultivation tests of winter wheat at the Nephi substation, 1909 to 1913, inclusive.

SPRING CULTIVATION OF WINTER WHEAT.

Two adjacent plats have been used each year since 1909 for testing the value of spring cultivation of winter wheat compared with no cultivation. These plats were treated uniformly in every other respect. Normal cultivation consists of harrowing the crop, usually with a spike-toothed harrow, as early in the spring as advisable, repeating this operation, if necessary, before the plants are in boot.

The chief value of spring cultivation, it was thought, would be found in its favorable influence upon the yield of the crop by breaking the crust which usually forms upon the surface of the ground during the winter and early spring. The destruction of this crust was

[1] Cardon, P. V. Cereal investigations at the Nephi substation. U. S. Dept. Agr. Bul. 30, p. 34, 1913.

expected to create a mulch which would prevent the evaporation of soil moisture and allow the plant greater freedom for growth. These factors constitute the basis of a great deal of argument in favor of the spring cultivation of winter wheat, a practice which is rather general in the Great Basin area. The results obtained are quite contrary to those which were expected.

YIELD OF GRAIN.

The annual and average yields of the plats for 1909 to 1913, inclusive, are given in Table XIII and are shown graphically in figure 16.

TABLE XIII.—*Annual and average yields of winter wheat obtained from cultivated and uncultivated plats at the Nephi substation, for the years 1909 to 1913, inclusive.*[1]

Treatment.	Yield per acre of grain (bushels).					
	1909	1910	1911	1912	1913	Average.
Cultivated	8.33	19.00	27.90	14.90	9.83	15.99
Not cultivated	12.66	19.50	27.70	14.90	10.50	17.05

[1] The Koffoid variety was used in 1909, while the Turkey was used in 1910 to 1913, inclusive.

It is of peculiar interest to note that in four of the five years there has been practically no difference in the yields obtained in this test. The yield of the noncultivated plat has been higher in three of the five years, while in 1911 the difference of 0.2 of a bushel per acre favored the cultivated plat. The yields of 1912 were identical. The difference in the average yield of 1.06 bushels in favor of the noncultivated plat is largely due to the greater yield of this plat in 1909.

EFFECT ON SOIL MOISTURE.

Soil samples were taken each year from each of the plats, usually at the beginning, in the middle, and at the end of the season. Six-foot samples were taken, and the moisture content of each foot section was determined in the manner previously described in this bulletin. The results are presented in Table XIV, which shows the annual and average percentage of moisture in each foot and for the entire 6 feet in the spring, in the summer, and in the fall.

Table XIV shows a marked uniformity in the moisture content of the two plats at the beginning, in the middle, and at the end of the season, the seasonal loss from both plats being about the same. The greatest difference was shown in 1909, when the cultivated plat with a thin stand of grain lost moisture less rapidly than the noncultivated plat, on which the stand was thicker. In all other years the stands were more nearly alike. Figures 17, 18, and 19 illustrate graphically the results shown in Table XIV. It is apparent that spring cultivation of winter wheat did not conserve any appreciable amount of

moisture in the 6 feet of soil sampled and that, so far as moisture conservation is concerned, no advantage was derived from the cultivation of the crop.

TABLE XIV.—*Annual and average percentages of moisture in each of the first 6 feet of soil on the plats used in the test of spring cultivation of winter wheat at the Nephi substation, samples taken in spring, summer, and fall, for the years 1909 to 1913, inclusive.*

Treatment and date of determination.	Depth of sampling.						Average.
	1 foot.	2 feet.	3 feet.	4 feet.	5 feet.	6 feet.	
CULTIVATED.							
1909:							
June 26	12.60	16.25	18.02	18.50	19.25	17.63	17.04
August 12	12.75	15.20	15.45	18.95	16.70	12.82	15.31
1910:							
May 15	13.05	16.30	17.33	17.70	18.15	19.95	17.08
June 28	10.38	12.63	11.33	11.18	13.30	16.90	12.62
August 6	8.53	11.35	11.10	11.15	13.10	11.38	11.10
1911:							
April 26	18.28	21.90	20.46	18.90	17.80	15.65	18.83
September 20	9.12	12.13	11.95	11.48	14.72	13.42	12.14
1912:							
May 15	20.17	21.51	20.17	17.99	15.21	17.04	18.68
June 27	9.92	13.11	12.14	14.25	15.23	16.23	13.48
August 2	9.48	13.65	12.24	11.52	13.99	17.30	13.03
1913:							
May 17	20.50	22.22	21.38	18.32	15.98	15.54	18.99
June 20	10.83	15.77	15.63	15.73	15.54	15.06	14.76
September 6	10.67	13.49	12.24	11.43	13.58	12.49	12.32
Average in spring	18.00	20.48	19.84	18.23	16.79	17.05	18.40
Average in summer	10.93	14.44	14.28	14.92	15.83	16.46	14.72
Average in fall	10.11	13.16	12.60	12.91	14.42	13.48	12.78
NOT CULTIVATED.							
1909:							
June 26	13.15	16.15	17.20	17.28	16.85	15.22	15.97
August 12	10.65	12.90	12.20	10.15	11.05	13.45	11.73
1910:							
May 15	14.35	17.65	18.95	18.20	18.35	19.45	17.82
June 28	12.98	11.83	11.78	11.05	13.20	17.95	13.13
August 6	8.75	11.88	11.65	11.75	13.10	17.85	12.50
1911:							
April 26	18.79	22.69	21.79	19.60	19.07	17.78	19.95
September 20	8.91	13.39	13.08	12.51	15.13	13.25	12.71
1912:							
May 15	16.77	21.35	20.21	20.22	19.21	17.20	19.16
June 27	12.04	14.15	14.05	18.00	16.17	15.99	15.07
August 2	10.61	13.69	12.62	12.67	14.78	16.72	13.52
1913:							
May 17	18.88	20.59	20.20	19.10	17.12	19.04	19.16
June 20	10.73	15.80	17.21	15.91	16.23	16.95	15.47
September 6	11.30	12.88	12.29	12.05	15.18	13.83	12.92
Average in spring	17.20	20.57	20.29	19.28	18.44	18.37	19.02
Average in summer	12.23	14.48	15.06	15.56	15.61	16.53	14.91
Average in fall	10.04	12.95	12.37	11.83	13.85	15.02	12.68

EFFECT OF CULTIVATION ON THE PLANTS.

As already stated, the spring cultivation of winter wheat was expected to allow the plants greater freedom for development. It is not known to what extent this result obtained, but it is reasonable to believe that the surface of the soil was placed in better condition for plant development than where the crust was left unbroken and the plants compelled to push through it. It is, however, almost impossible to break the crust without injuring some plants. Whether this injury is offset by the benefit to others is difficult to determine,

though the yields of the past five years indicate that it is not. An effort was made in 1913 to determine the exact extent of the injury to the plants by harrowing with a spike-toothed harrow, the teeth of which were set almost perpendicularly. At this time there was a heavy crust on the ground, which the plants were penetrating with difficulty.

On May 21, when the plants were from 3 to 4 inches high, four areas were staked off on plat 22D, and the plants in each area were counted before the plat was harrowed. Each area was 3.3 feet square, thus containing $\frac{1}{4000}$ of an acre, so that the total area of the

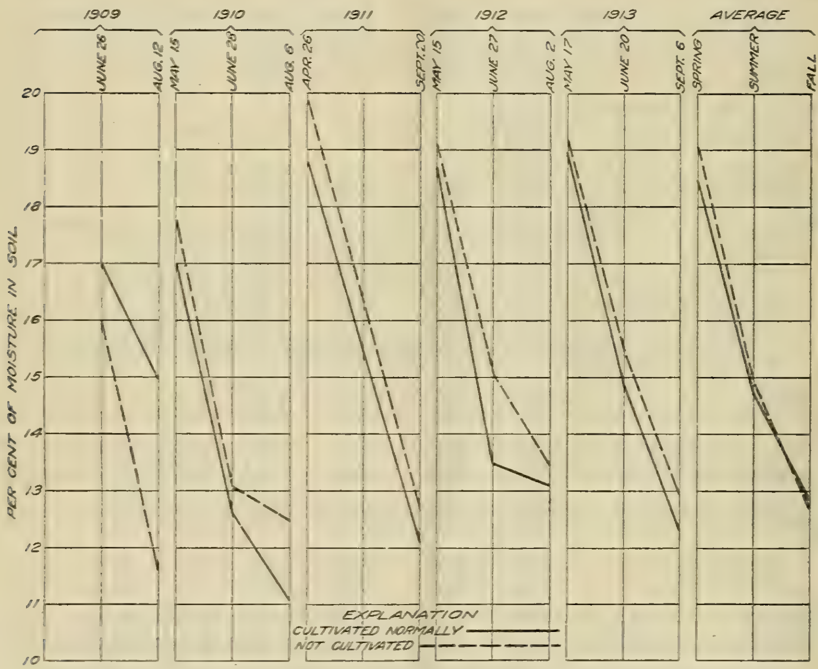

FIG. 17.—Graphs showing the average percentage of moisture in the first 6 feet of soil at the beginning, in the middle, and at the end of the crop season, as found in the spring-cultivation tests of winter wheat at the Nephi substation, 1909 to 1913, inclusive.

four units equaled $\frac{1}{1000}$ of an acre. About one week after harrowing, the plants in each area were counted again and the loss due to harrowing was determined. On the basis of the figures obtained, the stand was 218,000 plants per acre before and 193,000 plants per acre after harrowing, a loss of 25,000 plants, or 11.54 per cent. This loss alone would allow the plants greater freedom for development, and it might be expected to increase the number of culms per plant.

To determine the effect of harrowing on the production of culms the total number per unit area was determined just before harvest and the average number of culms per plant calculated. The average

number on the cultivated plat was 4.17, while on the uncultivated plat it was 4.05. The particular areas which were counted on the uncultivated plat, however, showed a thinner stand than those on the cultivated plat, so that the number of culms per plant does not show entirely the difference in development. The number of plants per acre on the uncultivated plat, as indicated by the areas counted, was 165,000 with a total of 663,000 culms. On the cultivated plat, the stand was 193,000 plants to the acre, with 805,000 culms, which was over 21 per cent more than on the uncultivated plat. On only one of the four uncultivated areas counted was the stand as thick as on the cultivated areas. On this area the average number of culms

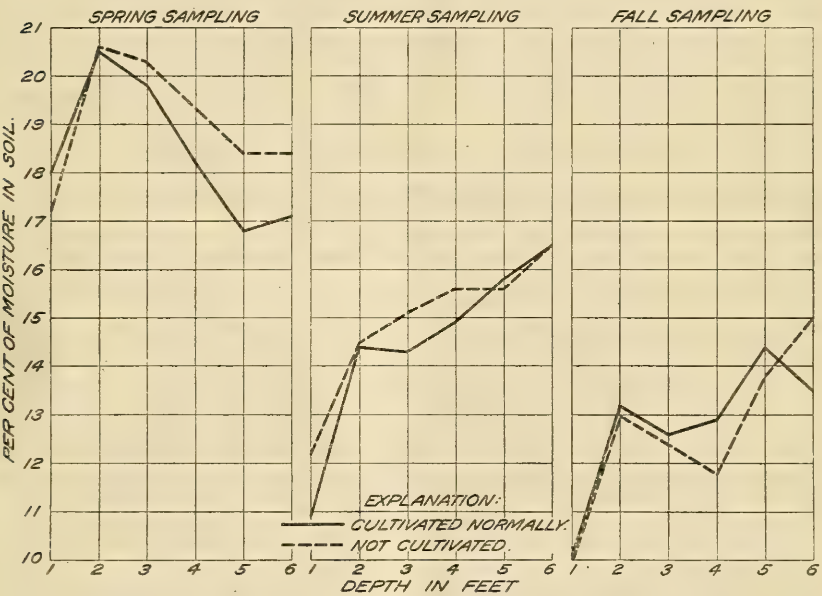

FIG. 18.—Graphs comparing the average percentage of moisture in each of the upper 6 feet of soil at the beginning, in the middle, and at the end of the crop season, as found in the spring-cultivation tests of winter wheat at the Nephi substation, 1909 to 1913, inclusive.

per plant was 3.74. On a cultivated area, with practically the same stand, the number of culms per plant was 4.14, an increase of 11 per cent.

On the same areas on the uncultivated plats the average yield per unit area 3.3 feet square was 156 grams of straw and 103 grams of grain. On the areas in the cultivated plats the yields were 199 grams of straw and 114 grams of grain. These figures indicate that cultivation caused a marked increase (27.6 per cent) in yield of straw, but a much smaller increase (10.7 per cent) in yield of grain. The yields obtained on the unit areas are contradictory to those from the entire plats, as shown in Table XIV, which shows a decrease in yield on the cultivated plat of 6.4 per cent.

TIME OF HARVESTING WINTER WHEAT.

During the period from 1909 to 1912, inclusive, a test of the effect of the time of harvesting upon the yield and quality of winter wheat was conducted. The milling and chemical tests of the wheat were made by the division of chemistry of the Utah station, but the data are not available at this time. Only the data on yield will be presented here.

FIG. 19.—Graphs showing the average seasonal decline in the percentage of moisture in each of the upper 6 feet of soil, as found in the spring-cultivation tests of winter wheat at the Nephi substation, 1909 to 1913, inclusive.

The four plats used in this test lay side by side and were treated uniformly up to and subsequent to the time of harvesting. One of these plats was harvested when the kernel was in the green-dough stage and one each week thereafter until all were harvested. In this way the grain was cut in four different stages of maturity, namely, green dough, hard dough, fully ripe, and overripe. The annual and average yields of the plats for the four years are given in Table XV.

TABLE XV.—*Annual and average yields of winter wheat harvested at four different stages of maturity at the Nephi substation, for the years 1909 to 1912, inclusive.*

Stage of maturity when harvested.	Yield per acre of grain (bushels).				
	1909	1910	1911	1912	Average.
Green dough	7.83	8.80	20.30	6.50	10.86
Hard dough	8.83	14.00	26.40	10.20	14.86
Fully ripe	6.33	13.80	24.60	11.50	14.06
Overripe	8.50	12.70	20.70	11.80	13.43

Table XV shows that with one exception the yield each year favored harvesting in the hard-dough stage, though the differences are not great. The earliest harvest gave the smallest yields, due probably to the shrinking of the grain. The small decrease in the average yield from hard dough to overripe was probably due to shattering at harvest time.

FREQUENCY OF CROPPING LAND TO WINTER WHEAT.

One of the first tests begun by the Utah experiment station on the Nephi farm was planned to determine the relative return from cropping land to winter wheat continuously, every second year, one year in three, and two years in three. This test was conducted on four fifth-acre plats until the fall of 1907, when five tenth-acre plats were added, to allow the production of a crop under each condition each year. Since 1907, then, nine plats have been used.

The total yields per acre of the four fifth-acre plats obtained previous to 1908, the annual and total acre yields of all the plats from 1908 to 1913, and the total yields of the fifth-acre plats from 1904 to 1913, inclusive, are reported in Table XVI.

TABLE XVI.—*Annual and total yields of winter wheat obtained from continuous and alternate cropping and from growing one and two crops in three years at the Nephi substation, 1904 to 1913, inclusive.*

Frequency of crop.	Yield per acre of grain (bushels).								
	Total yield, 1904 to 1907.[1]	1908	1909	1910	1911	1912	1913	Total, 1908 to 1913.	Total, 1904 to 1913.
Continuous	60.20	13.41	14.58	7.80	5.70	6.00	4.50	51.99	112.19
Alternate	50.80	32.66	Fallow.	9.90	Fallow.	4.80	Fallow.	47.36	98.16
Do		Fallow.	2.50	Fallow.	28.00	Fallow.	1.83	32.33	
Two crops in three years	25.10	32.74	13.42	Fallow.	23.60	3.90	Fallow.	73.66	98.76
Do		Fallow.	2.50	10.30	Fallow.	6.50	6.83	26.13	
Do		21.16	Fallow.	8.20	8.10	Fallow.	2.33	39.79	
One crop in three years	49.10	Fallow.	Fallow.	5.00	Fallow.	Fallow.	11.17	16.17	65.27
Do		Fallow.	3.50	Fallow.	Fallow.	10.80	Fallow.	14.30	
Do		19.16	Fallow.	Fallow.	27.00	Fallow.	Fallow.	46.16	

[1] Taken from Bulletin 112 of the Utah Agricultural Experiment Station.

The data presented in Table XVI are not wholly dependable, principally because winterkilling so reduced the yields in some years that their comparative value was almost wholly lost. The volunteer crops on the continuously cropped plat and the plat cropped two years in three were less affected by winterkilling than the sown crops, for the reason that they made more growth in the fall. As a result, uncontrollable factors, such as thin stands, weeds, etc., caused wide variations in the results, which did not indicate the true value of the methods employed.

The continuously cropped plat has not failed completely, however, in any year, even in the very dry years 1910 and 1911. In 1911, when there was very little winterkilling and good growing conditions prevailed, the continuously cropped plat and that cropped two years

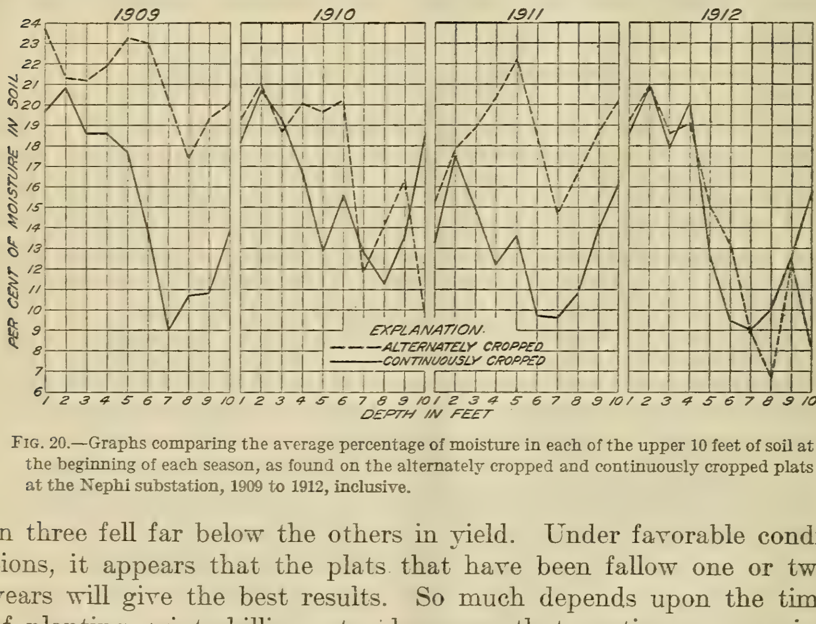

FIG. 20.—Graphs comparing the average percentage of moisture in each of the upper 10 feet of soil at the beginning of each season, as found on the alternately cropped and continuously cropped plats at the Nephi substation, 1909 to 1912, inclusive.

in three fell far below the others in yield. Under favorable conditions, it appears that the plats that have been fallow one or two years will give the best results. So much depends upon the time of planting, winterkilling, etc., however, that continuous cropping sometimes appears to be profitable, owing to the survival of volunteer grain.

The severe winterkilling in some years completely offsets the advantage of some plats in high soil-moisture content. This is well illustrated by figure 20, from which it will be seen that in 1909 the difference in moisture content of the continuously cropped plat and the alternately cropped plat was greatly in favor of the latter at the beginning of the season, yet, because of a better stand, due to the volunteer grain, the continuously cropped plat yielded nearly seven times as much as the other, as is shown in Table XVI. In 1910 the differences, though less marked, were much the same as those of

the previous year. In 1911, however, under favorable conditions, the yields were consistent with the soil moisture. In 1912 there was little difference either in moisture or yield.

These results indicate that where a good stand is obtained in the fall and little winterkilling follows, the crops following fallow will yield more than those grown on continuously cropped land. To determine the relative value of the two systems of cropping, the cost of growing a crop and of maintaining a fallow must also be taken into consideration. In the vicinity of Nephi, the cost of growing and harvesting wheat is about $3 per acre more than the cost of maintaining a fallow throughout the year. This extra cost must be charged against the crop which is obtained in alternate years on the continuously cropped land. On this basis, the 14 bushels greater yield per acre in 10 years from the land continuously cropped have been obtained at a cost of $15, for the $3 extra cost has been incurred five times in the 10 years. This extra cost is greater than the value of the increased yield, which is further evidence that alternate cropping and fallowing is preferable to continuous cropping to wheat.

INTERTILLED CROPS COMPARED WITH FALLOW IN ALTERNATION WITH WINTER WHEAT.

The most direct attempt made at the Nephi substation to find a successful substitute for the alternation of a cereal crop and summer fallow has been in a simple rotation in which winter wheat was grown after fallow and after corn, peas, and potatoes in rotation. As this test has been in progress since 1908 sufficient data have been accumulated to justify consideration at this time. An outline of the rotation is given in Table XVII.

TABLE XVII.—*Rotation of intertilled crops and fallow alternating with wheat.*

Plat.	1908	1909	1910	1911	1912	1913
12B	Wheat	Fallow	Wheat	Fallow	Wheat	Fallow.
13B	...do	Corn	...do	Peas	...do	Potatoes.
14B	...do	Potatoes	...do	Corn	...do	Peas.
15B	...do	Peas	...do	Potatoes	...do	Corn.
12C	Fallow	Wheat	Fallow	Wheat	Fallow	Wheat.
13C	Potatoes	...do	Corn	...do	Peas	Do.
14C	Peas	...do	Potatoes	...do	Corn	Do.
15C	Corn	...do	Peas	...do	Potatoes	Do.

TREATMENT OF PLATS.

The four plats which had grown wheat were plowed in the fall of each year to a uniform depth of about 8 inches. The land then received no cultivation until the next spring, when it was double disked or harrowed sufficiently to destroy all weeds and make a good fallow or a good seed bed. The plat to be summer-fallowed was treated normally in the spring and throughout the summer. The

corn, peas, and potatoes were planted in rows far enough apart to permit intertillage, the cultivation during the summer being practically the same for the cropped and the fallow plats. The corn and peas were drilled in rows about 35 inches apart, while the potatoes were dropped behind a plow in hills 24 inches apart in rows 3 feet apart.

After the crops were harvested from these plats in the usual manner in the fall, winter wheat was sown on them and on the fallow plat at

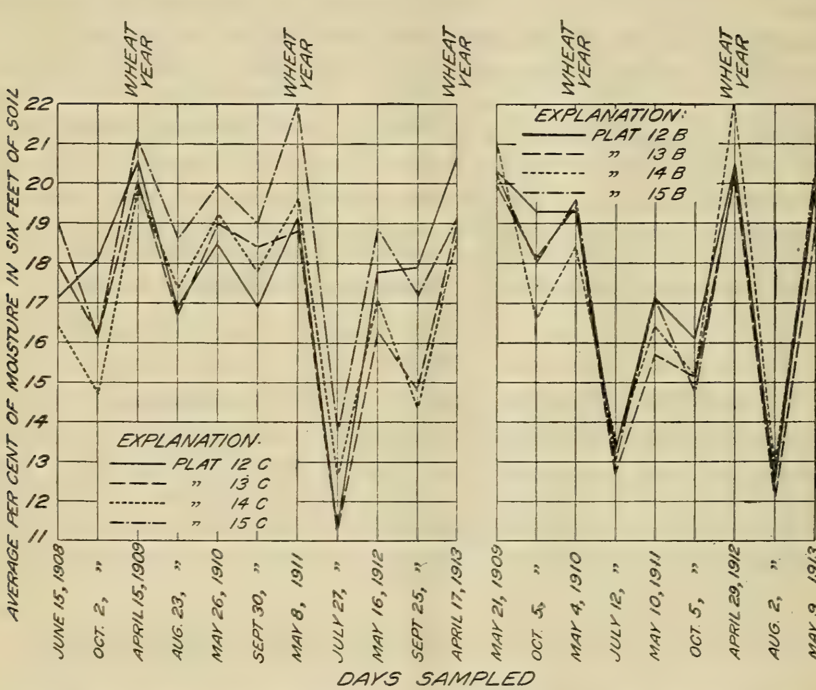

FIG. 21.—Graphs showing the average percentage of moisture in the first 6 feet of soil at the beginning and at the end of each season, as found in the rotation experiments at the Nephi substation, 1908 to 1913, inclusive.

the same rate and on the same date. The subsequent treatment of the plats was identical in every respect.

MOISTURE CONTENT OF THE SOIL.

Soil-moisture determinations were made on the plats in the rotation during each year of the test. The plats growing wheat were sampled at the beginning, in the middle, and at the end of each season, while the other plats were sampled about once a month during the season. The moisture content of each foot of soil to a depth of 6 feet was determined in the usual manner.

The results indicate that there was very little difference in the moisture content of any foot of soil on the different plats. The varia-

tions favored one plat one year and another plat the next, changing so frequently that no one plat had any marked advantage. The average moisture content in the first 6 feet of soil on all plats in the rotation at the beginning and end of each season from 1908 to 1913, inclusive, is shown graphically in figure 21. It will be noted that the average moisture content of the plats was usually surprisingly uniform, and that no great difference existed in any case. During the wheat years the moisture content of all plats was reduced to a minimum, but during the alternate years the moisture content remained reasonably constant.

YIELDS OBTAINED.

The yields of the various crops obtained in these rotation experiments are presented in Table XVIII. No attention should be paid to the yields of wheat from the "B" plats in 1908, as they were occupied by four different varieties in the regular varietal test, and varietal differences probably affected the yields. In all other years the same variety was used on all plats.

TABLE XVIII.—*Yields obtained in tests of winter wheat [1] in alternation with fallow and with corn, peas, and potatoes in rotation at the Nephi substation, for the years 1908 to 1913, inclusive.*

[Yields per acre (wheat and potatoes in bushels, corn and peas in pounds).]

Plat.	1908		1909		1910	
	Crop.	Yield.	Crop.	Yield.	Crop.	Yield.
12B	Wheat	27.50	Fallow		Wheat	13.7
13B	do	25.83	Corn (fodder)	1,240	do	19.3
14B	do	30.16	Potatoes	84.7	do	17.2
15B	do	22.66	Peas (vines)	1,050	do	18.3
12C	Fallow		Wheat	4.66	Fallow	
13C	Potatoes	42.50	do	2.50	Corn (fodder)	40
14C	Peas {Vines Seed	1,080 220	do	2.16	Potatoes	7.35
15C	Corn {Fodder Grain	630 17.5	do	6.50	Peas (vines)	35

Plat.	1911		1912		1913	
	Crop.	Yield.	Crop.	Yield.	Crop.	Yield.
12B	Fallow		Wheat	14.7	Fallow	
13B	Peas	Failure.	do	17.8	Potatoes	34.5
14B	Corn (fodder)	40	do	18.8	Peas {Vines Seed	95 20
15B	Potatoes	4	do	18.7	Corn {Fodder Unshelled grain	550 200
12C	Wheat	30	Fallow		Wheat	2.0
13C	do	28.5	Peas {Vines Seed	225 90	do	4.2
14C	do	32.1	Corn (fodder)	1,420	do	4.4
15C	do	29.5	Potatoes	32.4	do	4.2

[1] In 1908 the wheat plats were a part of the regular varietal test, so that the results for that year should be disregarded. The varieties were as follows: On plat 12B, Crimean (C. I. No. 1433); plat 13B, Crimean (C. I. No. 1435); plat 14B, Crimean (C. I. No. 1436); and on plat 15B, Koffoid (C. I. No. 2997). In 1909 the last-named variety was grown on all plats, while in 1910 and succeeding years the Turkey variety (C. I. No. 2998) was used.

Wheat after corn gave the highest yield obtained in 1909, while wheat after fallow yielded better than wheat after either potatoes or peas. The yields of 1909, however, were extremely low because of excessive winterkilling. Consequently they would be practically worthless if they were not relatively the same as those obtained in later years. In 1910 wheat after fallow yielded much less than wheat after any intertilled crop. In 1911 wheat after potatoes gave the highest yield, while there was little difference in the yields of the other plats. Wheat after fallow again gave the lowest yield in 1912 and 1913. A summary of the wheat yields obtained in this test for the five years from 1909 to 1913, inclusive, is given in Table XIX.

TABLE XIX.—*Annual and average yields of winter wheat obtained after corn, potatoes, peas, and fallow, at the Nephi substation, for the years 1909 to 1913, inclusive.*

Rotation.	Yield per acre of grain (bushels).					
	1909	1910	1911	1912	1913	Average.
Wheat after corn	6.50	19.30	28.50	18.80	4.40	15.50
Wheat after potatoes	2.50	17.20	32.10	18.70	4.20	14.94
Wheat after peas	2.16	18.30	29.50	17.80	4.20	14.39
Wheat after fallow	4.66	13.10	30.00	14.70	2.00	12.89

Table XIX shows that the average yield of wheat for five years was less after fallow than after corn, potatoes, or peas.

A summary of the total crop yields of all plats since the test began is given in Table XX, where it will be noticed that plats 12B and 12C, wheat after fallow, have given the lowest total returns per acre.

TABLE XX.—*Summary of total crop yields from the intertillage and fallow rotation plats at the Nephi substation, 1908 to 1913, inclusive.*

Years and plats.	Total yields per acre.					
	Wheat.	Corn.		Peas.		Potatoes.
		Grain.	Fodder.	Seed.	Hay.	
	Bus.	Bus.	Lbs.	Lbs.	Lbs.	Bus.
1909 to 1913:						
12B	28.40					
13B	37.10	None.	1,240	Failure.	Failure.	34.50
14B	36.00	None.	40	20	95	84.70
15B	37.00	2.9	550	None.	1,050	4.00
1908 to 1913:						
12C	36.66					
13C	35.20	None.	40	90	225	42.50
14C	38.66	None.	1,420	220	1,080	7.35
15C	40.20	17.5	630	None.	35	32.40

Table XX shows that the wheat yields on the "B" series are greatly in favor of the plats which produced an intertilled crop in alternate years, the differences in acre yields varying from 8 to 9 bushels. In addition to yielding as much wheat as plat 12C, the

other plats on the "C" series have given good yields of the intertilled crops. From these results it appears that the production of intertilled crops had some effect on the soil which was beneficial to the following wheat crop. It is difficult to determine the nature of this effect, but that it was present can not be doubted.

The intertilled crops were sometimes unprofitable, in some instances total failures, but the losses thus accruing were offset by profitable yields in more favorable seasons. The cost of growing these crops was somewhat higher than the cost of maintaining fallow, but the yields of the intertilled crops and the higher wheat yields following made up for this difference in cost. It is quite impossible to determine with any great degree of satisfaction the relative value of these rotations, since the total yields of some of the intertilled crops were so small, and because the production of such crops on the dry lands of the Great Basin is practically unheard of, there is no standard for estimating values. Perhaps the greatest value that will come from the results of the above experiment will be to point out the possibilities of such a rotation and to encourage greater effort in the development of better varieties of intertilled crops or better methods of producing the varieties now used.

SUMMARY.

The Nephi substation is located in the Juab Valley, in the eastern part of Juab County, in central Utah. The soil in this locality is very deep. It ranges from clay to sandy loam. In the virgin state it is covered with a dense growth of black sagebrush.

The average annual precipitation in the Juab Valley during the past 16 years was 13.40 inches. During the progress of the experiments reported herein (1908 to 1913), the precipitation in 1908 and 1909 was above normal, while in 1910, 1911, 1912, and 1913 it was below normal. The winter and spring precipitation is the heaviest of the year. The rains of summer have been small and consequently of little value to the growing crops.

The average evaporation at the Nephi substation during the six months from April to September, inclusive, has been about 45 inches. The average wind velocity for any one day has not exceeded 10 miles per hour. Protracted hot winds are unknown. Only two months of the year, July and August, have been free from frost. Normally, however, there are from 90 to 100 days in the frost-free period, extending from about June 15 to September 15.

Most of the experiments reported upon have been in progress since 1908. A few are of longer duration, while some were begun as late as 1911. The tests have dealt with stubble treatment immediately after harvest; time and depth of plowing; cultivation of

fallow; seeding, cultivation, and harvesting the crop; frequency of cropping; and diversity of crops in rotation.

The tests dealing with stubble treatment immediately after harvest were begun in the fall of 1911. The results so far obtained are not conclusive enough to warrant publication.

The average results for five years, 1909 to 1913, inclusive, show that spring plowing was better than fall plowing for moisture conservation, in yield of grain, and in cost of producing the crop. Spring plowing gave an average yield of 18.5 bushels per acre, as compared with 16.8 bushels for fall plowing. Owing to this difference in yield and the lower cost of producing the crop, spring plowing gave a net acre profit of $3.03 more than fall plowing.

The results of five years show that there was no advantage in deep plowing or subsoiling over shallow plowing so far as moisture conservation is concerned. There was no material difference in the yields obtained from plats plowed at different depths, varying from 5 to 18 inches. The highest average yield was obtained from plats plowed 10 inches deep, and the lowest average yield was from the plats subsoiled 18 inches deep, while the 5-inch plowing yielded higher than the 15-inch subsoiling.

One year's results from a test of deep fall plowing and shallow spring plowing compared with shallow fall plowing and deep spring plowing show no difference in soil moisture and but slight difference in yield.

The results of five years' experiments on fall-plowed fallow show that the moisture of the cultivated plats remained practically the same throughout the season, while that of the uncultivated plats rapidly declined, until by fall it was reduced to a comparatively low point. It is probable that weeds and volunteer grain were important factors in this loss of moisture. The average acre yield of the cultivated plats was 17 bushels, as compared with 13 bushels on the uncultivated plats.

The results of one season on spring-plowed fallow show no difference in the moisture content of the plats cultivated or not cultivated. The yields, 11.9 and 9.5 bushels per acre, favor the noncultivated plat.

The results of 10 years show no correlation between the time of sowing winter wheat and the yield, but the best yields have usually been obtained from plats seeded between September 1 and October 15. There was no significant difference between the average moisture content of the plats for any one or for all years. The chief problem in the time-of-seeding tests of winter wheat now seems to be a mechanical one involving some improvement of the machinery used in seeding. It is believed that this will obviate the necessity of

waiting for rain before seeding, thus permitting early seeding, which seems desirable, and allowing the crop time enough to make a fair growth before the advent of winter. Late planting is often followed by much winterkilling, which completely offsets the value of any tillage method used in preparing the land and of the quantity of moisture stored in it.

The average result of five years' tests shows no difference in the yields of winter wheat seeded at different depths. The yields were greatly influenced by conditions at seeding time.

The ordinary drilling of winter wheat has given more profitable yields than broadcasting or cross drilling.

The results of three years' experiments show that winter wheat sown at the rate of 4 to 5 pecks per acre is more profitable than when sown at 3 pecks per acre, the rate ordinarily used on the dry lands of the Great Basin.

The average yields of five years favor no spring cultivation of winter wheat. The noncultivated plats yielded 17.05 bushels, as compared with 15.99 bushels from those cultivated. There was no apparent difference in the moisture content of the plats. A test made in the spring of 1913 showed that 11.54 per cent of the plants were killed by one harrowing. This loss offsets all benefits that might have come from harrowing.

The results of four years favor harvesting when the grain is in the hard-dough stage.

Where a good stand was obtained and little winterkilling followed, winter wheat after fallow yielded more than winter wheat on continuously cropped land. This depended largely upon the season, however, and the continuously cropped plat, owing to volunteer grain, yielded as well or better than other plats in the test in seasons of much winterkilling.

The average acre yield of winter wheat for five years was less after fallow than after corn, potatoes, or peas.

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November 10, 1914.

(PROFESSIONAL PAPER.)

THE NITROGEN OF PROCESSED FERTILIZERS.

By Elbert C. Lathrop,
Scientist in Soil Fertility Investigations.

INTRODUCTION.

Organic compounds have lately taken on a deeper significance in their relation to the complex problems of the soil and of crop production, for not only do they affect the physical conditions and chemical reactions of the soil but they also have been shown to be directly connected with fertility or infertility, some of them being essentially beneficial to the growth of plants, while others are distinctly harmful. Of the organic compounds thus far isolated from soils, a large number contain nitrogen, and of these nitrogenous substances, some have been found rather widely distributed in soils varying as to location, climate, methods of cropping, etc. These nitrogenous compounds occur either as plant constituents or arise from the decomposition of plant or animal protein, brought about by the various biological and biochemical agents in the soil. Not only compounds of this class found in soils but also many other protein decomposition products have been studied, both alone and in conjunction with the three fertilizer elements, in respect to their action on plant growth, and they have been shown in a number of cases to exert a beneficial influence; furthermore, these complex compounds are available for use by the plant without first being changed by chemical or biochemical means into ammonia and then to nitrates.[1]

That these facts have an immense practical bearing on fertilizers and the fertilizer industry, both from the standpoint of the producer and of the consumer, is at once obvious. The old high-grade nitrog-

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[1] A Beneficial Organic Constituent of Soils: Creatinine. By Oswald Schreiner, E. C. Shorey, M. X. Sullivan, and J. J. Skinner. Bul. 83, Bur. Soils, U. S. Dept. Agr., 1911.

Nitrogenous Soil Constituents and Their Bearing on Soil Fertility. By Oswald Schreiner and J. J. Skinner, Bul. 87, Bureau of Soils, U. S. Dept. Agr., 1912.

This investigation is a contribution to the knowledge of the nature of the changes brought about in the manufacture of some of the processed fertilizers, and of the character and availability of such processed goods in mixed fertilizers when used in farm practice.

enous fertilizers, such as cottonseed meal, dried blood, fish scrap, etc., are being used more and more for feed purposes, and the time can not be far distant when their use as fertilizers will cease to be economic; thus a necessity for other and cheaper fertilizers of this type arises. Coupled with this is the desire of the chemist and the manufacturer to utilize in one way or another all waste products, whatsoever their nature, so that the number and kinds of nitrogenous materials which are used in the manufacture of fertilizers is on the increase. Described in the patent literature and found on the market are a large number of fertilizers which may be characterized as "processed," that is, the crude materials, not in themselves permissible as fertilizers, are made to undergo some decided chemical change to render them suitable as plant nutrients. It has been found that the "availability" of the crude substances is nearly always greatly increased by such processing and that a much larger percentage of the nitrogen in the finished product is soluble in water, although the actual chemical changes produced seem to have received little attention. The chemical compounds in processed fertilizers which are here shown to have direct fertilizer significance have not been determined, other than to show that ammonia is formed during processing and that ammonia is more readily produced from the processed goods.

Since the wastes from which this type of fertilizer is made contain more or less protein, or proteinlike substances, it seemed quite obvious that the finished fertilizers must contain more or less of the chemical compounds which would arise by such treatment from pure proteins in the laboratory. Since the action on plants of many of this class of compounds has been determined it is evident that the finding of such compounds in the fertilizers would throw much light on the question of the "availability" of the nitrogen in the fertilizer itself.

BASE GOODS A TYPE OF PROCESSED FERTILIZER.

For a chemical study of processed fertilizers a sample of "wet-mixed" or "base goods" fertilizer was chosen as a representative of this type of fertilizer material. The base goods was obtained directly from the factory for use in this investigation. This fertilizer is made by the treatment of various trade wastes and refuse, such as hair, garbage tankage, leather scraps, etc., with rock phosphate and the requisite amount of sulphuric acid. These materials are mixed together in a "den" and the resulting mass is allowed to stand for several days, until it is cool enough to be conveniently handled. In the course of the reaction the mass reaches a temperature approximating 100° C., and the identity of the original substances is almost or entirely lost. Under these conditions it is certain that more or less

hydrolysis of the proteins in the crude materials takes place, with the formation of proteoses, peptones, polypeptides, or the simple amino acids, the kinds and number of products formed necessarily depending on the proportion of the different proteins in the original materials, on the amount and strength of the acid, the length of time of the reaction, and the temperature reached during the treatment.

Hartwell and Pember [1] have recently made a study of base goods in order to determine the availability of the nitrogen contained in it as compared with that of the high-grade nitrogenous fertilizers. The product which they used was made from hair tankage, garbage tankage, and roasted leather, together with rock phosphate and sulphuric acid. From their report the following figures for the analysis of the crude materials used in producing the fertilizer and of the finished product are taken·

TABLE I.—*Total nitrogen in cruae materials and finished product. (Hartwell and Pember.)*

	Nitrogen.
	Per cent.
Hair tankage	6.28
Roasted leather	6.49
Garbage tankage	2.87
Base goods, including the above	1.68
Water soluble nitrogen in base goods	1.28
Water insoluble nitrogen in base goods	.40

TABLE II.—*Percentage of the total nitrogen present in different forms. (Hartwell and Pember.)*

	Before putting into the den.	After removing from the den.
In ammonia	6.5	14.3
In water soluble organic matter	7.8	57.7
In water insoluble organic matter	85.7	28.0

The experimental work of the present investigation was along two separate lines: (1) Analytical, involving total nitrogen determinations and the separate estimation of the various forms in which nitrogen may occur; (2) a determination of the definite chemical compounds present in the fertilizer by suitable methods of isolation and identification.

THE CHEMICAL EXAMINATION OF BASE GOODS.

TOTAL NITROGEN AND AMMONIA.

Total nitrogen.—The total in the base goods was determined by the Kjeldahl-Gunning-Arnold [2] method and was found to be 1.61 per cent.

[1] J. Ind. Eng. Chem., 4, 441 (1912).

[2] U. S. Dept. Agr., Bureau of Chemistry, Circ., 108, 15 (1912); T. C. Trescot, J. Ind. Eng. Chem., 5, 914 (1913).

Ammonia.—Considerable difficulty was experienced in obtaining concordant results in the determination of the nitrogen in the form of ammonium salts. Boiling weighed amounts of the base goods with water and magnesium hydroxide, according to the official method,[1] for the determination of ammonia in fertilizers, did not give duplicate results sufficiently close for the purpose of this research. Owing to the acidity of the sample, it was impractical to use barium carbonate, but litharge was used with varying results. Finally, the determination was made by using the vacuum distillation method, which gave concordant results. This method, which gives only the nitrogen found as ammonia or as ammonium salts, is used for the determination of amide nitrogen in the products of acid hydrolysis of proteins. A weighed quantity of the fertilizer was placed in a Claisen flask connected up with a cooled receiver of 1 liter capacity and a small guard flask of 200 cubic centimeters capacity. Both flasks contained 0.1 N sulphuric acid. To the fertilizer was added 100 c. c. of neutral 95 per cent alcohol and 100 c. c. of distilled water, together with enough 10 per cent suspension of calcium hydroxide to make the mixture decidedly alkaline in reaction. The ammonia was then distilled under a pressure of from 10 to 12 mm., the temperature of the bath not exceeding 40° C. In the table which follows are given the results obtained by the three methods here used for the determination of ammonia.

TABLE III.—*Nitrogen in the form of ammonia or ammonium salts.*

Method.	Expressed in per cent of base goods.	Expressed in per cent of total nitrogen in base goods.
Magnesium hydroxide distillation	0.380	23.60
	.389	24.16
Lead oxide distillation	.394	24.47
	.420	26.09
Vacuum distillation	.374	23.23
	.374	23.23

An examination of these results shows that by boiling with magnesia or litharge, somewhat more nitrogen is found as ammonia than really exists in this form in the base goods. It is therefore probable, that there are in the base goods nitrogenous compounds which are broken down into ammonia by the action of these alkaline reagents at a temperature of 100° C. The use of magnesia at boiling temperature for the purpose of determining the amount of ammonia split off by acid hydrolysis from certain proteins which contained cystine, was found to give unreliable results.[2] The reason for this

[1] Bul. 107, 9 (Revised), Bureau of Chem., U. S. Dept. Agr.

[2] Embden, quoted by Gümbel, Hofmeister's Beiträge, 5, 297 (1904): Hart, Zeit. physiol. Chem., 33, 354, 1901); Folin, ibid., 39, 476 (1903); Denis, J. Biol. Chem., 8, 427 (1910).

was found to be that magnesia under such conditions changes a part of the amino nitrogen of cystine into ammonia. In this laboratory it was also found that by boiling cystine with lead oxide one of the amino nitrogen groups of this compound was split off almost quantitatively, with the concurrent splitting off of hydrogen sulphide. Furthermore, it has been shown that if the amide nitrogen from protein hydrolysis is determined by distillation with a weak alkali, such as calcium hydroxide, at a temperature not to exceed 40° to 42° C. in the bath and at a pressure of from 10 to 12 millimeters, no decomposition of cystine takes place.[1]

In the manufacture of base goods the hair which is used contains proteins which on acid hydrolysis yield a high percentage of cystine. This fact, together with the analytical results just discussed, suggest rather strongly that there is present in the base goods more or less cystine, although this evidence can not be considered conclusive, since it is possible that in such a heterogeneous mixture there may be present other nitrogenous compounds which would be decomposed by magnesia or litharge with the liberation of ammonia.

NITROGEN PARTITION.

For the purpose of determining the different forms of nitrogen present in the base goods the method of Van Slyke[2] was followed in its essential details, except that the determination of cystine, was not made. The method for the determination of this compound, according to the procedure used by Van Slyke, depends not upon a nitrogen determination but upon the determination of the amount of sulphur in the compounds precipitated by phosphotungstic acid. This determination when made on the hydrolytic products of acid digestion of pure protein may give quite satisfactory results, but the raw materials from which base goods are made contain many organic compounds other than proteins or protein decomposition products, and this is of course particularly true in the case of garbage tankage. It is well known that many plant and animal substances contain sulphur in a variety of linkages, and garbage tankage no doubt contains sulphur in other forms than that of cystine. The hair and leather used have both undergone some decomposition before the acid treatment and it is not impossible that the cystine originally present in the proteins may have been changed into sulphur compounds of a different chemical nature. No doubt some sulphur compounds other than cystine are precipitated by phosphotungstic acid, so that a determination of cystine depending on the sulphur content of the phosphotungstic acid precipitate would be of uncertain value in dealing with material of unknown origin and of such a heterogeneous character as fertilizer goods.

[1] Gümbel, Hofmeister's Beiträge, 5, 297 (1904).

[2] J. Biol. Chem., 10, 15–55 (1911).

It should also be stated that although the results from the Van Slyke analysis are expressed in the usual way, arginine N, histidine N, etc., that it is not intended to convey the impression that these fractions contain pure arginine, histidine, etc., since as will be shown later, other compounds are included under these analytical terms. However, the nitrogen so expressed is that which is contained in compounds which give the various reactions upon which the Van Slyke method depends.

Two 20-gram samples of base goods were extracted for analysis. The first sample was extracted with boiling water until the extract ceased to give an acid reaction. The second sample was boiled for 24 hours with hydrochloric acid, sp. gr. 1.115, the resulting solution was filtered by suction and the insoluble residue washed with hot water until the washings ran free from chlorides. The two extracts were then concentrated to the consistency of a sirup in vacuo to expel the free volatile acid, and each was finally made up to a volume of 250 c. c.

Total nitrogen.—Total nitrogen in solution was determined by subjecting 50 c. c. of the solution to Kjeldahl analysis. The water extract contained 1.372 per cent and the hydrochloric-acid extract 1.435 per cent of the base goods.

Amide nitrogen.—Amide nitrogen was determined by distilling in vacuo the remaining 200 c. c. of solution, to which were added 100 c. c. of 95 per cent alcohol and 20 c. c. of a 10 per cent suspension of calcium hydroxide, as described under the determination of ammonia. The water extract contained 0.374 per cent and the hydrochloric acid extract 0.882 per cent.

Humin nitrogen.—The residue from the amide nitrogen determination was used for the determination of humin nitrogen. The precipitate, formed by the addition of calcium hydroxide, was filtered off and washed with distilled water in the same manner in which Van Slyke directs that the phosphotungstic acid precipitate be washed. The washing was continued until no reaction for chlorides or alkalinity was obtained. The nitrogen remaining in the precipitate and in the filter paper was then determined by Kjeldahl analysis. The humin nitrogen was 0.031 per cent for the water extract and 0.074 per cent for the hydrochloric acid extract.

Diamino acid nitrogen.—The combined filtrate and washings from the humin precipitate were neutralized with hydrochloric acid, concentrated in vacuo to a volume of about 100 c. c. and then transferred to a 300 c. c. Erlenmeyer flask. To this solution were added 18 c. c. of concentrated hydrochloric acid together with 15 grams of purified phosphotungstic acid [1] and the whole diluted with water to a volume of 200 c. c. The flask was placed on a steam bath and heated until

[1] Winterstein, Zeit. physiol. Chem., 34, 153 (1901).

the phosphotungstates were almost redissolved, when it was set aside for 48 hours in order to allow them to recrystallize and fully precipitate. The precipitate was then filtered, washed, and dissolved in 45 per cent sodium hydroxide as described by Van Slyke. The phosphotungstic acid was precipitated with barium chloride and filtered off. The filtrate and washings from this precipitate were concentrated in vacuo and made up to a volume of 200 c. c.

Arginine nitrogen.—Arginine nitrogen was determined in 100 c. c. of this solution by boiling with 12.5 grams of solid potassium hydroxide for six hours and collecting the ammonia formed in 0.1 N sulphuric acid. Under these conditions one-half of the nitrogen in the arginine and 18 per cent of the nitrogen of cystine is split off as ammonia.

Total nitrogen in the diamino acid solution.—Total nitrogen in the diamino acid solution was found by subjecting the solution remaining after the arginine determination to Kjeldahl analysis and adding to the ammonia so obtained the amount obtained from the arginine nitrogen determination.

Amino nitrogen.—Amino nitrogen was determined by means of the Van Slyke apparatus.[1]

From these three figures the nitrogen was calculated as arginine N, histidine N, and lysine N according to the two formulas:

(1) Histidine N = 1.667 non-amino N − 1.125 arginine N;

(2) Lysine N = total N − (arginine N + histidine N).

The results obtained were as follows: For the water extract arginine 0.111 per cent, histidine nitrogen 0.117 per cent, and lysine nitrogen 0.081 per cent; for the hydrochloric-acid extract they were 0.104, 0.070, and 0.117 per cent, respectively.

Total nitrogen of the monoamino acids.—To the combined filtrate and washings from the phosphotungstic acid precipitate 45 per cent caustic soda was added until the solution became turbid by the precipitation of lime; acetic acid was then added until the solution cleared. This solution was placed in a 500 c. c. flask and made up to the mark. Total nitrogen was estimated in 100 c. c. portions, using the Kjeldahl method.

Amino nitrogen.—Amino nitrogen in the form of monoamino acids was determined by use of the Van Slyke apparatus.

From the two figures obtained the amount of nitrogen present as *non-amino nitrogen* in monoamino acids was found by difference. The amino nitrogen in the form of monoamino acids in the water extract was 0.543 per cent and in the hydrochloric acid extract 0.546 per cent. The non-amino nitrogen in the monoamino acid fraction of the water extract was 0.114 per cent and in the hydrochloric acid extract it was 0.133 per cent.

[1] For the description of this apparatus and the details of the procedure employed, see: Van Slyke, Jour. Biol. Chem., 12, 275 (1912).

Van Slyke has shown that certain corrections must be applied in the method, owing to the fact that the phosphotungstates of the diamino acids are slightly soluble, and these corrections have been applied just as though the fractions contained only the hydrolysis products of pure proteins. In Table V the combined results of the analyses are given.

The above analytical procedure which separates the nitrogen into different groups, gives results than can only be rigidly interpreted when the products of the acid hydrolysis are known. The results of the analysis of base goods by this method can only be clearly understood when further facts regarding the compounds, in which the nitrogen is contained, are discovered. A description of the methods used in isolating and identifying certain of these compounds follows.

ISOLATION AND IDENTIFICATION OF DEFINITE COMPOUNDS FROM THE PROCESSED FERTILIZER.

Ten pounds of base goods were extracted by boiling for 1 hour with 20 gallons of water in a steam-jacketed kettle. The solution was filtered from the insoluble residue, made exactly neutral with caustic soda, the precipitate formed filtered off, and the filtrate concentrated in a steam kettle to a volume of about 3,500 c. c.

This solution contained phosphates, sulphates, and much other mineral matter. In order to separate as much of these salts as possible from the organic compounds a cold saturated solution of barium hydroxide was added to the solution until no further precipitation took place. The heavy precipitate which formed was filtered off by suction and washed many times with water. The filtrate was exactly neutralized with sulphuric acid and concentrated to a volume of about 2,000 c. c. After cooling, this solution was made acid to 5 per cent with sulphuric acid and a solution of phosphotungstic acid was added to slight excess, and the mixture allowed to stand.

After 3 days the precipitate which formed was filtered off and washed with water containing about 5 per cent sulphuric acid and a little phosphotungstic acid. The precipitate was carefully dissolved in 45 per cent caustic-soda solution, using phenolphthalein as an indicator and adding at no time more than two drops of the alkali solution. Water was added so that a volume of about 1,500 c. c. was reached, and barium hydroxide solution was added until the phosphotungstic acid was precipitated. After filtering off the barium phosphotungstate, the free alkali was just neutralized with sulphuric acid, and the solution was then evaporated almost to dryness with barium carbonate in order to expel all of the ammonia. The residue was taken up in about 1,000 c. c. of hot water and filtered, and the precipitate washed with hot water. The filtrate was placed in a 5-liter flask and treated while hot with solid silver sulphate, which was added slowly until the

solution contained sufficient to give a yellow precipitate, when a drop was removed and tested with a solution of barium hydroxide. The solution was then filtered, and the separation of the three hexone bases was carried out according to the method of Kossel and Kutscher.[a] The solution was cooled to 40° C. and saturated with finely powdered barium hydroxide. The precipitate which was formed was collected and stirred up in a mortar with solid barium hydroxide, when it was again filtered off and washed with barium-hydroxide solution. This precipitate contains the silver salts of histidine and arginine, while the filtrate contains the lysine.

Lysine.—The above filtrate was acidified with sulphuric acid and freed from silver with hydrogen sulphide. Lysine was precipitated from this solution as the phosphotungstate, and the free base was obtained by decomposing this salt with barium hydroxide. From a concentrated solution of the base, which was strongly alkaline in reaction and which showed no tendency to crystallize on standing, the picrate salt was prepared. This compound showed the solubility, characteristic crystalline appearance, and properties of lysine picrate.[b] When taken up in boiling water and allowed to crystallize slowly, it formed in rather large yellow prisms, but when in small amount the crystals assumed a fernlike appearance. The lysine was further identified by the preparation from the picrate of the hydrochloride salt, $C_6H_{14}O_2N_2.2\ HCl$, and the platinum chloride salt, $C_6H_{14}O_2N_2.H_2Pt\ Cl_6+C_2H_5\ OH$.[c]

The silver precipitate which would contain the arginine and histidine was suspended in water acidified with dilute sulphuric acid and broken up with hydrogen sulphide. The silver sulphide was filtered off, the sulphuric acid was removed with barium hydroxide solution, and after filtering the solution was made slightly acid with nitric acid. Silver nitrate solution was added until a test drop with barium hydroxide gave a yellow precipitate. Histidine was completely precipitated as the silver salt by the careful addition of barium hydroxide solution. The precipitate was washed with barium hydroxide solution until the washings ceased to give a test for nitrates.

Histidine.—The histidine silver was suspended in water acidulated with sulphuric acid and treated with hydrogen sulphide. The procedure described by Kossel and Kutscher was followed, and the histidine was finally separated as the dihydrochloride salt. The method of obtaining this compound and the characteristic crystalline form of the dihydrochloride salt[d] are sufficient to establish its identity as histidine.

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[a] Zeit. physiol. Chem., **31**, 166 (1900).
[b] Kossel, Zeit. physiol. Chem., **25**, 180 (1898); **26**, 586 (1899).
[c] Hedin, Zeit. physiol. Chem., **21**, 299 (1895).
[d] Schwantke, Zeit. physiol. Chem., **29**, 492 (1900); Kossel, ibid., **22**, 182 (1896).

Arginine.—The method of isolating arginine is simply a further step in the method used in the isolation of histidine. Arginine was isolated first as the acid nitrate salt, which crystallized in the form of plates,[1] and was further identified by preparing the neutral nitrate salt and the copper nitrate salt both in characteristic crystalline form.

Monoamino acids.—The filtrate from the phosphotungstic acid precipitate was made alkaline with barium hydroxide in order to remove the sulphuric and phosphotungstic acids, and filtered. The filtrate was concentrated and nearly neutralized with sulphuric acid. This slightly alkaline solution, about 500 c.c. in volume, was treated by boiling with freshly prepared copper hydroxide, and was then poured into about 3,000 c.c. of 95 per cent alcohol and allowed to stand over night, in order that the insoluble mineral matter might settle out. The deep-blue alcoholic solution was then filtered, the insoluble salts redissolved in water, and reprecipitated by pouring into alcohol as before. The alcoholic solutions were combined and evaporated to dryness, the residue was taken up in hot water and the copper removed by treatment with hydrogen sulphide. After filtering from the copper sulphide, the solution, which contained considerable color, was boiled with animal charcoal. The filtered solution was made faintly alkaline with ammonia and treated with freshly precipitated copper hydroxide, keeping the volume of the solution at about 1,000 c.c. The solution was filtered from the excess of copper hydroxide and evaporated to dryness on the steam bath. The solid residue was then scraped from the sides of the dish and extracted in a Soxhlet extractor with absolute methyl alcohol until no further blue color was imparted to the alcohol.

Leucine.—The alcohol insoluble portion was dissolved in a large volume of boiling water and the copper removed with hydrogen sulphide. The solution was filtered, boiled down to a volume of about 50 c.c. and treated with ammoniacal lead acetate until no further precipitation took place. The precipitate was washed with 95 per cent alcohol and was finally decomposed with hydrogen sulphide after suspending in water. On concentration of a portion of this solution the characteristic crystals of impure leucine formed. These crystals separated in concentric nodules closely resembling fat, but which were composed of concentrically grouped highly refracting needles. These crystals were redissolved in water and added to the original solution which was boiled up with animal charcoal until the color disappeared. The leucine was then purified as before by the formation of the copper salt and the basic lead salt. On concentrating the solution obtained from this purification, crystals of pure leucine were obtained. These crystals formed in pearly scales, which somewhat

[1] See Gulewitsch, Zeit. physiol. Chem., 27, 178 (1899).

resemble cholesterin. When dry the crystals were light, had a satiny glossy appearance, and were not easily wet again with water, They were extremely soluble in hot water and quite easily soluble in cold water. Leucine was further identified by the fact that it sublimed,[1] and by the crystalline form and solubility of the copper salt,[2] and by its two color reactions with quinone,[3] red with a solution of leucine and quinone and violet when in addition sodium carbonate was used.

Tyrosine.—The methyl alcohol solution of the copper salts was evaporated to dryness, and the residue taken up in water. The copper was removed with hydrogen sulphide and the solution was boiled with animal charcoal. After filtering, the solution was concentrated and long thin silky needles began to separate. These needles, which closely resembled tyrosine, were filtered off, and the filtrate further concentrated, when another crop of needles was obtained. These were filtered off and added to the first fraction and were then extracted with boiling 70 per cent alcohol. The crystalline residue was recrystallized from water a number of times and dried on a porous plate. This compound crystallized in the stellate groups of long slender silky needles which are characteristic of tyrosine. These crystals were relatively insoluble in cold water,[4] very insoluble in cold 90 per cent alcohol, easily soluble in hot water, and were tasteless, colorless, and infusible. The compound was further identified as tyrosine by the formation of the copper salt, which was rather insoluble in cold water and fairly easily soluble in hot water, by the fact that a solution of the compound gave a red color when boiled with Millon's reagent,[5] and that a sulphonic acid prepared from the compound gave a violet color with ferric chloride.[6]

Purine bases.—Five pounds of base goods were boiled up with 10 liters of water, filtered, neutralized and concentrated to a volume of about 2,500 c. c. The solution was made strongly alkaline with sodium hydroxide and the purine bases were precipitated with Fehling's solution and dextrose according to the method of Balke.[7] The supernatant liquid was decanted from the copper precipitate and this was washed, until free from alkali, with a solution of sodium acetate, by repeated decantations. The precipitate was filtered, freed from sodium acetate by washing with alcohol, and the copper removed by suspending the precipitate in water and treating it with hydrogen sulphide. After filtering off the copper sulphide the solution was concentrated and the purine bases reprecipitated by means

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[1] Schwanert, Liebig's Ann., **102**, 224 (1857).
[2] Hofmeister, Liebig's Ann., **189**, 16 (1877).
[3] Wurster, Centrlb. Physiol., **2**, 590 (1889).
[4] Erlenmeyer and Lipp., Liebig's Ann., **219**, 161 (1883).
[5] Millon, Compt. rend., **28**, 40 (1849); Lassaigne, Ann. Chem. Phys. (2) **45**, 435 (1830).
[6] Piria Liebig's Ann., **82**, 252 (1852).
[7] Jour. prakt. Chem. [2], **47**, 537 (1893).

of a solution of silver nitrate and ammonia. After washing with water the silver precipitate was boiled with 10 c. c. of nitric acid, specific gravity 1.1, and filtered. From this solution, on cooling and standing, crystals were deposited which were filtered off.

The filtrate was diluted with water, made alkaline by the addition of ammonia, and a solution of silver nitrate added. No precipitate was formed showing the absence of xanthine.

Guanine.—The precipitate from the nitric acid solution was washed with water, suspended in water, and decomposed with hydrogen sulphide. The solution was filtered and concentrated to about 10 c. c. when strong ammonia was added producing a white gelatinous precipitate which was filtered off and washed with a little cold water. The precipitate was dissolved in a little warm hydrochloric acid and tested for the presence of guanine by means of the xanthine reaction and Weidel's test, both of which were positive. From the remainder of the solution the characteristic picrate of guanine described by Capranica [1] and the dicromate described by Wulff [2] were prepared. The method of obtaining this base, its solubility in water, ammonium hydroxide, and hydrochloric acid, the solubility of the silver salt in nitric acid, specific gravity 1.1, the color reactions, and the formation of the two characteristic salts, the picrate and dichromate, are sufficient to establish the identity of the compound as guanine.

Hypoxanthine.—The filtrate from the ammonia precipitation of guanine was boiled to expel all the ammonia and to a portion of the solution a solution of picric acid was added, but no precipitate was immediately formed, showing the absence of adenine. To another portion of the solution hydrochloric acid was added and the solution was concentrated when crystals resembling those of hypoxanthine hydrochloric separated out in whetstonelike crystals or bunches of prisms. Hypoxanthine forms a characteristic silver nitrate salt[3] and a characteristic silver picrate salt[4] both of which are crystalline and relatively insoluble in water. Hypoxanthine does not give the xanthine reaction, but when treated with nitric acid and bromine water a yellow color is produced which on addition of sodium hydroxide turns red, and on heating acts like the xanthine reaction. By means of these reactions the substance was identified as hypoxanthine.

THE CHEMICAL CHANGES INVOLVED IN PROCESSING.

The compounds which were isolated from the base goods are tabulated in Table IV according to the sources from which they have been derived and the chemical groups to which they belong. While it was not possible to isolate these compounds in a strictly quantitative manner, nevertheless it was evident that the purine bases were

[1] Zeit. physiol. Chem., **4**, 233 (1880).
[2] Ibid., **17**, 477 (1893).
[3] Neubauer, Zeit. analyt. Chem., **6**, 34 (1867).
[4] Bruns, Zeit. physiol. Chem., **14**, 555 (1890).

present in exceedingly small quantities, although the method used in their isolation was subject to no more error than some other of the isolation methods; this would indicate that the nitrogen of the purine bases makes up but a small percentage of the total nitrogen present in the fertilizer.

TABLE IV.—*Organic compounds isolated from sample of base goods.*

Compound.	Chemical group.	Source of compound.
Arginine	Diamino acids or hexone bases.	Products of protein hydrolysis by acid treatment of raw materials.
Histidine		
Lysine		
Leucine	Monoamino acids	
Tyrosine		
Guanine	Purine base	Plant constituent, or product of hydrolysis of nucleoprotein.
Hypoxanthine	do	Plant constituent, or product of conversion of nucleoprotein-base.

Purine bases.—It will be noticed that the two purine bases are listed in the table as coming from different sources. It is a well-known fact that the purine bases may exist in plant tissues and plant extracts as such; that is, they are not linked up in more complex compounds in such a way that their peculiar chemical identity is lost. In the garbage which has entered into the manufacture of the fertilizer there were doubtless many sorts of plants or plant remains which contained some or all of the purine bases, and this fact alone would account for the presence of hypoxanthine and guanine in the finished product. This, however, is not the only source of the purine bases. Levene [1] and his associates have demonstrated that some of the purines enter into the composition of the nucleic acids, which are decomposition products of nucleoprotein and that they may be obtained by a process of hydrolysis from these nucleic acids. Of the four purine bases commonly encountered, only guanine and adenine have been found to be constituent parts of the nucleic acid molecule, it matters not whether the nucleic acid be a decomposition product of animal or plant nucleoproteins. But it has been shown that the two purines found in the nucleic acids may be changed, both by chemical and biochemical agencies, into the two other purine bases, xanthine and hypoxanthine, so that these are frequently encountered. Thus by the treatment of guanine with nitrous acid Fischer [2] changed it into xanthine and in the same manner Kossel [3] changed adenine into hypoxanthine. Furthermore, Schittenhelm and Schröter [4] have shown that the putrifactive bacteria, especially the colon bacillus,

[1] Levene and Jacobs, Ber., **44**, 746 (1911); Biochem. Zeit., **28**, 127 (1910); Levene, Abderhalden's Biochem. Arbeitsm., II, 605 (1910); Ibid., V, 489 (1911).

[2] Liebig's Ann., **215**, 309 (1882).

[3] Zeit. physiol. Chem., **10**, 258 (1886).

[4] Zeit. physiol. Chem., **41**, 284 (1904).

were able to convert adenine and guanine into hypoxanthine and xanthine. They also show that the bacteria have the power of splitting the nucleic acid itself. This same change is also brought about by the action of certain enzymes, such as erepsin, on nucleic acid.

With these facts at hand it is possible to draw the following conclusions as to the source of the two purine bases in this fertilizer: The guanine and hypoxanthine may be derived from plant remains which originally contained these two compounds; the guanine may arise by the acid hydrolysis of certain vegetable or animal nucleoproteins which were present in the original materials; and the hypoxanthine may have been formed by the processes of natural decomposition, such as the action of bacteria and enzymes, which had taken place in the crude materials before they were subjected to the acidulation process or during the process itself. It is not improbable that the guanine and hypoxanthine come from all of these sources.

Diamino acids.—Of the three diamino acids lysine was obtained in much the largest amount, arginine next, and histidine in the smallest amount. These compounds are products of protein hydrolysis by acids, but may also be produced under certain conditions by the action of bacteria. Since one or more of the diamino acids have been found to be present in every protein so far examined, and since the method for the analysis and the isolation of these bases is almost quantitative, the determination of the number and amounts of the diamino acids present in a mixture of protein hydrolysis products is of importance in deciding the nature and character of the original material which entered into the processed goods.

Monoamino acids.—Although leucine and tyrosine, which are protein decomposition products, were found in about the same quantities, the methods of isolation were so far from being quantitative that this relationship is of no significance. The isolation and identification of the other monoamino acids from the complex products of protein hydrolysis can only be accomplished, in the majority of cases, by means of the esterification method of Emil Fischer. This method is not a strictly quantitative one and requires large amounts of materials for a successful separation, and consequently was not used in this investigation. The use of methods other than that of esterification failed to isolate any other monoamino acid in quantities large enough for identification. As will be shown later, a number of monoamino acids besides the two isolated must be present in the processed goods.

Establishing the presence of these products of acid hydrolysis of proteins, namely, the diamino acids, arginine, lysine, and histidine, and the two monoamino acids, leucine and tyrosine, in the amounts in which they were found is of itself sufficient evidence to demonstrate that by the acid treatment of the crude materials used in the manu-

facture of the base goods the proteins contained therein have been changed. This change is shown to be a deep-seated one, since five of the compounds which are known to be final products of protein hydrolysis by acids are found. This, however, can not be taken to mean that the proteins have been completely hydrolysed by the acid treatment since it is possible to have present in the product of partial hydrolysis of proteins not only the diamino and monoamino acids, but also such intermediate compounds as polypeptids, peptones, proteoses, etc.

In this connection the results obtained by use of the Van Slyke method, which are given in Table V, are of particular interest. As has been already stated, the base goods were extracted (1) with boiling water and (2) with boiling acid. In the former case only slight further hydrolysis of the materials in the base goods is to be expected since the free acid in the fertilizer is extremely weak, and the boiling temperature, 100° C., is that which was reached in the process of manufacture. In the case of the second extract complete hydrolysis of all the proteins or proteinlike materials is certainly to be expected, since in addition to the original hydrolysis the material was boiled with strong hydrochloric acid for 24 hours, which treatment in the case of most proteins is sufficient for complete hydrolysis. The differences in the results obtained from the analyses of the two extracts may, therefore, be expected to throw some light on the question of the completeness of hydrolysis of the original proteins by the acid processing.

TABLE V.—*Nitrogen forms as determined by the Van Slyke method.*

Form of nitrogen.	Results expressed in per cent of base goods.		Results expressed in per cent of total N in base goods.	
	H_2O extract.	HCl extract.	H_2O extract.	HCl extract.
Total N	1.610	1.610		
Total soluble N	[1] 1.372	1.435	[1] 85.24	88.64
Total insoluble N	[1] .238	[1] .175	[1] 14.76	[1] 11.36
Amide N	.374	.382	23.23	23.70
Humin N	.031	.074	1.95	4.61
Diamino acid fraction:				
Arginine N	.111	.104	6.89	6.46
Histidine N	.117	.070	7.26	4.38
Lysine N	.081	.117	5.06	7.26
Monoamino acid fraction:				
Amino N	.543	.546	33.75	33.92
Nonamino N	.114	.133	7.10	8.27

[1] Obtained indirectly.

First it will be noticed that total soluble nitrogen in the hydrochloric acid extract is 88.64 per cent of the total N, while that of the water extract is 85.24 per cent, showing a difference of 3.4 per cent soluble N produced by further hydrolysis of the materials in the base goods. Correspondingly there is a decrease of insoluble N.

There is an increase of 0.47 per cent amide N in the hydrochloric acid extract over that in the water extract. This is due to the splitting off of ammonia from some nitrogenous compounds by the hydrochloric acid and suggests the presence of some product of partial protein hydrolysis in the fertilizer which contains an acid amide linkage.

The statement has already been made that nitrogenous compounds other than arginine, histidine, and lysine are included under the figures given for these compounds in the table. This is due to the fact that the phosphotungstic acid which is used as a precipitant of the diamino acids also precipitates peptones, proteoses, etc., as well as the purine bases, cystine, and possibly other compounds. Since nitrogen compounds other than proteins existing in the original material and susceptible to decomposition with hot acid, would have been already broken up in the processing, it follows that the changes produced by further boiling with acid would result from peptones, proteoses, etc. The difference noted between the results obtained from the two extracts for the diamino acids are therefore due to some interferring substances of the nature of proteins and not to such substances as the purines or cystine. Moreover, the latter compounds will produce the same relative error in analysis in the case of both extracts.

Of the diamino acids the only one determined directly is arginine. Its determination depends on the fact that when arginine is boiled for some time with strong potassium hydroxide, half of the nitrogen of the arginine is split off as ammonia. However, if cystine is present 18 per cent of its nitrogen is evolved as ammonia, together with the arginine nitrogen. As has already been stated this figure should be the same for the two extracts providing that there is present in the base goods no substance precipitated by phosphotungstic acid, and giving off ammonia when boiled with strong alkali or strong hydrochloric acid. A comparison of the results obtained for arginine in the two extracts shows that the figure for arginine in the water extract is higher than that of the hydrochloric acid extract by 0.43. In other words, there appear to be present in the diamino acid fraction compounds which on boiling with alkali give off ammonia amounting to 0.22 per cent of the total nitrogen. These compounds are broken up by the further hydrolysis with acid.

Further information may be obtained by a consideration of the figures for lysine and histidine, which are obtained not by a direct determination, but by calculation from the figures obtained for arginine N, total N in the fraction, amino N and non-amino N. Lysine contains only amino N, histidine contains one-third amino N and two-thirds non-amino N, while arginine contains one-fourth amino N and three-fourths non-amino N. Since histidine N is in a measure

obtained by difference from the non-amino N and the arginine N according to formula (1) on page 7, it is evident that if there are precipitated by the phosphotungstic acid compounds which contain non-amino N other than arginine and histidine, such nitrogen will be classed as histidine N, because the arginine N is determined directly.

A comparison of the results for histidine shows that there is 2.88 per cent less N calculated as histidine in the hydrochloric acid extract than in the water extract and at the same time there is an increase in lysine N in the hydrochloric acid extract amounting to 2.20 per cent. This shows that by the hydrolysis with hydrochloric acid some substance which reacted as though it contained non-amino N has been decomposed with the formation of an almost corresponding amount of amino N. Here again the indications are that this substance is of the class of compounds related to the proteins.

This is further borne out by the fact that in the monoamino acid fraction the nitrogen listed as amino N has increased in per cent 0.17 and the nitrogen as non-amino N has increased in per cent 1.17 by hydrolysis with hydrochloric acid.

A comparison of the figures for humin N shows an increase of 2.66 in the hydrochloric acid extract, but since the nature of the compounds in which this class of nitrogen exists is not understood no interpretation can be given to this figure.

Proteoses.—In order to prove the presence of some intermediate product of protein hydrolysis, which is thus indicated by analytical methods, an aqueous solution of about 2.5 pounds of base goods was made and the diamino acids were precipitated with phosphotungstic acid, in the presence of 5 per cent sulphuric acid. The precipitate which formed was allowed to stand over night and after filtering off it was washed well with 5 per cent sulphuric acid. The precipitate was dissolved in sodium hydroxide, the phosphotungstic acid precipitated by adding barium hydroxide solution, and after filtering the excess of barium was removed by adding sulphuric acid until a neutral reaction was obtained. Portions of this solution were tested for peptones, proteoses, etc., with the following results; The biuret test was positive; a precipitate was obtained on saturation of the solution with ammonium sulphate, or with sodium chloride; when the filtrate from the latter solution was treated with acetic acid a cloudy precipitate developed. Precipitates were also obtained with sulphuric acid, hydrochloric acid, phosphomolybdic acid and with phosphotungstic acid. A precipitate was formed on the addition of alcohol to the solution. This precipitate was filtered off, dissolved in dilute alkali, and on addition of very dilute copper sulphate solution the biuret reaction was again obtained. These reactions are those which are given by proteoses and by the proteins and confirm the conclusions

arrived at from the results obtained with the Van Slyke method. The Millon reaction and the Hopkins-Cole reaction were both negative, showing the absence from this proteinlike compound of the tyrosine and the tryptophane radicles.

A very large number of compounds intermediary between the protein and its primary hydrolysis products may occur, depending on a great variety of conditions so that the actual identification of the compound under discussion would be a difficult matter. However, the nature of this compound may be approximately determined by the results obtained in the study of the two extracts by the Van Slyke method. These results have been already discussed and they indicate the presence in the base goods of a compound of a proteose nature, which because it gives a biuret test, must be composed of at least three amino acids. The results indicate still further that the compound is composed of acid amide radicals, diamino acids, particularly lysine, and monoamino acids, those containing amino nitrogen and especially those containing non-amino nitrogen. Since the figures obtained by the nitrogen partition method are subject to a certain amount of error when applied to such a mixture the figures can only be taken as approximate for the various forms of nitrogen which make up this compound.

The figures given for arginine in the table are probably only influenced by any cystine present. Attempts to isolate cystine from the base goods failed, although it seems unlikely that this compound can be absent. The figures for histidine and lysine are undoubtedly too high, since they include all of the other nitrogenous compounds precipitated by phosphotungstic acid, so that the absolute amount of these compounds in base goods can not be correctly determined by this method. The figure given for the amount of amino nitrogen present as monoamino acids may be a little high, while the non-amino nitrogen figure is open to considerable error.

In Table VI are given the primary hydrolysis products of a number of proteins which may be present in the base goods. These results were obtained by the esterification method and show how the different proteins vary in the nature and amount of the units composing them. Many monoamino acids, besides leucine and tyrosine, occur in these proteins, and there must consequently be present in the base goods amino acids other than the two isolated. This is apparent from the composition of the various proteins shown in the table. Owing to the large amount of amide nitrogen present in the fertilizer, which was split off by the acidulation of the original proteins of the trade wastes, it may be concluded that considerable quantities of aspartic or glutamic acids are present in this sample of base goods.

The conclusions which are to be drawn from the results obtained by the examination of this fertilizer by means of the analytical and

isolation methods are as follows: The process by which the nitrogen of certain trade wastes, such as hair, leather, garbage, etc., is made more available, is recognized as a process of partial hydrolysis of the complex protein contained in such materials, resulting in ammonia, amino acids, etc., all of which are more available than the original protein material. This hydrolysis is almost complete, the nitrogenous compounds formed being principally the primary products of protein hydrolysis, together with a small amount of proteoselike compound which has not been fully decomposed.

TABLE VI.—*Products of acid hydrolysis of various proteins.*

Compound.	"Synotin" from cattle flesh.[1]	"Keratin" from sheep's horn.[2]	"Keratin" from sheep's wool.[3]	"Keratin" from horse's hair.[4]	Halibut muscle.[5]	Ox muscle.[6]	"Legumin" from pea.[7]
Glycine[8]	0.5	0.5	0.6	4.7	0.0	2.1	0.4
Alanine[8]	4.0	1.6	4.4	1.5	(?)	3.7	2.1
Valine	.9	4.5	2.8	.9	.8	.8	......
Leucine[8]	7.8	15.3	11.5	7.1	10.4	11.7	8.0
Isoleucine	......	......	......	......	......	......	......
Phenylalanine[8]	2.5	1.9	......	.0	3.1	3.2	3.8
Tyrosine[8]	2.2	3.6	2.9	3.2	2.4	2.2	1.6
Serine	......	1.1	.1	.6	(?)	(?)	.5
Cystine	......	7.5	7.3	8.0	......	......	......
Proline	3.3	3.7	4.4	3.4	3.2	5.8	3.2
Oxyproline	......	......	......	......	......	......	......
Aspartic acid[8]	.5	2.5	2.3	.3	2.8	4.52	5.3
Glutamic acid[8]	13.6	17.2	12.9	3.7	10.1	15.5	17.0
Tryptophane	......	......	......	......	(+)	(+)	(+)
Arginine[8]	5.1	2.7	......	4.5	6.4	7.5	11.7
Lysine[8]	3.3	.2	......	1.1	7.5	7.6	5.0
Histidine[8]	2.7	......	......	.6	2.6	1.8	1.7
Ammonia[8]	.9	......	......	......	1.4	1.1	2.1
Total	47.3	62.3	49.2	39.6	50.7	67.5	62.4

[1] E. Abderhalden and T. Saski, Zeit. physiol. Chem., **51**, 404 (1907).
[1, 2, 3] E. Abderhalden and A. Voitinovici, ibid., **52**, 348 (1907).
[4] E. Abderhalden and H. G. Wells, ibid., **46**, 31 (1905); A. Argiris, ibid., **54**, 86 (1905).
[5] T. B. Osborne and F. W. Heyl, Amer. J. Physiol., **22**, 433 (1908).
[6] T. B. Osborne and D. B. Jones, ibid., **24**, 437 (1909).
[7] T. B. Osborne and F. W. Heyl, J. Biol. Chem., **5**, 197 (1908).
[8] Physiological action on plant growth has been determined and reported in Bul. 87, Bureau of Soils, U. S. Dept. Agr.

AVAILABILITY OF THE NITROGEN OF ORGANIC FERTILIZERS.

The question of the availability of the different kind of nitrogen contained in organic fertilizers is one that has caused considerable discussion. A number of methods have been proposed for determining this factor, and while some of them give helpful results, all excepting the plant method are open to more or less objection. The reason for this is that the methods are empirical and the nature of the complicated compounds in which the nitrogen is linked in the fertilizer is unknown or only guessed. When these nitrogen compounds are known and their action on plants as well as the action of the compounds which will be formed from them during their decomposition in the soil, has been determined, then the question of the availability of the nitrogen of organic fertilizers can be understood. Originally it was held that plants were only able to use nitrogen when

it was offered to them in the form of nitrates; this idea, however, was modified when it was discovered that under certain conditions plants used ammonia or ammonium salts without their conversion into nitrates quite as well as they used the nitrates themselves. During the past few years it has been clearly demonstrated that plants not only use nitrogen in the form of nitrates and ammonia but that they can also use nitrogen in the form of complex organic compounds.[1] The action of a number of these nitrogenous compounds has been tested in this laboratory in conjunction with the three fertilizer elements and it has been found that in some cases the nitrogen compounds are not only used as a source of nitrogen for the growing plant, without any change in the compound, but that these compounds were apparently nitrate sparers; that is, the plant used them in preference to the nitrates. Instead, then, of only one kind of nitrogen compound, nitrate, or at most two, nitrate and ammonia, there appears to be a very large number of nitrogenous compounds which have properties of physiological importance to plant growth. The question of the availability of nitrogen compounds can therefore be answered only when the nitrogen compounds contained in the fertilizer can be determined in amount and at the same time classified according to their physiological action on plant growth. It is hardly necessary to state that such a method does not exist at present and that the physiological action of only a part of the total number of nitrogenous compounds present in fertilizers is known.

The physiological action on plants of all of the nitrogenous compounds isolated from base goods has been determined by means of water cultures[2] and the results obtained may be stated briefly, as follows: Both of the purine bases are used by the plant as a source of nitrogen and are beneficial to plant growth; furthermore, the hypoxanthine acts as a nitrate sparer, there being less nitrate used by the plant in the presence of hypoxanthine than when the hypoxanthine is absent. Histidine, arginine, and lysine[3] are all beneficial to plant growth, causing nitrogen increases in the plant, and the two first diamino acids act as nitrate sparers; this may also be true of lysine, although this property of lysine has not been studied. Leucine is also beneficial to plant growth, and tyrosine, in the light of later investigations, is somewhat doubtful in action. Of the other monoamino acids which may be present in base goods, aspartic acid, glutamic acid, and glycocoll have been found to be beneficial. The action of alanine is somewhat doubtful, it apparently being beneficial in low concentrations, and the action of phenylalanine is reported as harmful. Thus we see that six of the seven compounds

[1] Hutchinson and Miller, Centralbl. f. Bakt., 30, 513 (1911); Schreiner and Skinner, Bul. 87, Bureau of Soils, U. S. Dept. Agr., 1912.

[2] Bul. 87, Bureau of Soils.

[3] Unpublished data.

isolated from the base goods are actually available to plants as such and have a beneficial action. Of the monoamino acids, other than the two isolated from base goods, which have been studied in regard to their action on plant growth, three have been found to be beneficial, one doubtful, and one is reported as being harmful.

The high-grade nitrogenous fertilizers, such as dried blood, are considered to have a high availability owing to the fact that the nitrogenous materials when placed in the soil quickly undergo the process of ammonification and nitrification, the nitrogen thus being changed into a form which can be immediately used by the plant. In fact, Lipman [1] has proposed a method for the determination of the availability of the nitrogen of organic fertilizers, depending on the amount of ammonia produced under certain conditions in a given length of time. It is evident from the above consideration that such a method does not tell the whole story, since in the decomposition of protein materials like dried blood intermediate compounds are formed which are undoubtedly in themselves beneficial to plant growth. In order, therefore, to understand the complete action of the nitrogenous materials in the base goods it is necessary to know how the compounds contained in it are acted upon by ammonifying bacteria. Jodidi [2] has shown that the amino acids, and acid amides are quite readily ammonified when placed in the soil, the rate of ammonia formation and the amount of ammonia formed depending apparently upon the chemical structure of the particular compound under consideration. In general, he found that the simpler the chemical structure of the nitrogen compound the more quickly and readily it was ammonified. In the light of these facts it appears that polypeptids, peptones, proteoses, and proteins would be ammonified still more slowly than the amino acids since their structure is increasingly more complex.

Hartwell and Pember [3] in their study on the availability of the nitrogen of base goods, by means of plant tests found that it had apparently as high an availability as dried blood; the water soluble nitrogen having even a higher availability. From the nature and amounts of the compounds present in the base goods this might be predicted. In the case of the dried blood, the nitrogen is practically all in the form of complex protein material which must be broken down into simpler compounds by bacterial action, with the formation of ammonia and other nitrogenous compounds, some or all of which may be of physiological importance to plants. With the base goods the case is a little different, the greater part of the nitrogen is at once available for plant use, and at the same time these available compounds may be changed more easily and quickly by the bacteria

[1] Bul. 246, New Jersey Expt. Sta., 1912.
[2] Research Bul. No. 9, Iowa Expt. Sta.
[3] Loc. cit.

of the soil into ammonia and nitrate, which in turn are used by the plant. The soluble nitrogen of base goods should therefore be in a more readily available form than the nitrogen of dried blood or other nitrogenous fertilizers which are entirely of a protein nature.

THE CHEMICAL PRINCIPLES UNDERLYING THE UTILIZATION OF NITROGENOUS TRADE WASTES.

In these days of conservation and scientific management more and more attention is being paid to the trade wastes from the various industries and to the municipal scrap heaps. Things which were formerly thrown away are now often made to pay for the entire cost of production. After the resources of the chemist and inventor have failed in finding any other use for some industrial waste, if it be of a nitrogenous nature, the fertilizer industry is turned to as a last resort. Here, however, all is not plain sailing since many of these nitrogenous substances are of such a nature that the nitrogen is said to be "unavailable" for plant use, that is, the substance is of such a nature that it is not readily decomposed by the natural agencies at work in the soil, so that for the purpose of plant nutrition the nitrogen of such substances is worthless or of little value. In order to render available this type of nitrogenous material many different kinds of treatment have been suggested, and the patent literature abounds in inventions of this sort.

It has already been stated that in order that the plant may make use of the nitrogen of even high-grade organic fertilizers, it is necessary for the proteins therein to be at least partially decomposable by the biological and biochemical agencies of the soil. The low-grade organic nitrogenous fertilizers resist decomposition by these biological and biochemical soil agencies, and their nitrogen is therefore considered to be less available for plant use. The guiding idea behind the processes proposed for the treatment of trade wastes, which will not decompose easily in the soil as such, is to change the nitrogen compounds contained in them in such a way that ammonia is formed and that their decay in the soil is more rapid.

Much of the nitrogenous materials in trade wastes is of a protein nature, since the products from which these wastes are derived are either of animal or vegetable origin. Such is the case with the wastes used in the manufacture of base goods. It has been shown that by the process used in the case of this fertilizer the nonavailable nitrogenous materials have been made highly available, not only because the nitrogen compounds can be ammonified quickly in the soil, but also because these compounds are directly utilizable by plants. This change in the nature of the nitrogen compounds has been brought about by the partial hydrolysis of the proteins contained in the various trade wastes used in the manufacture of the fertilizer. When proteins

decompose through natural conditions, be they in the soil or out of it, a certain amount of hydrolysis of the proteins takes place and if the decomposition is allowed to proceed long enough under proper conditions complete hydrolysis will result.

The principle involved in making the nitrogenous material in the soil available and in increasing the availability of low-grade nitrogenous materials by factory treatment is therefore the same. In other words, the general chemical principle to be applied in making available the nitrogen of low-grade fertilizers, trade wastes, etc., is that of complete or partial hydrolysis by any suitable means of the proteins contained in the wastes. Partial hydrolysis of proteins may be accomplished by means of heat, boiling, steaming, heating under pressure, and both partial and complete hydrolysis may be obtained by treating with strong acids or alkalis, either in the cold for a long time or heating to a high temperature, the extent of hydrolysis depending on the several conditions. In a number of processes already in use various of these treatments are practiced, resulting in different degrees of hydrolysis of the original proteins. While the availability of the nitrogen of a fertilizer depends on the substances in which the nitrogen is contained, it also depends on the extent of hydrolysis of the proteins used in the manufacture. It may be stated that in general the more extended and final the hydrolysis the more available the nitrogen of the compounds formed, since as has been shown, the final products of hydrolysis are utilized by the plant as such and are at the same time more readily changed into ammonia by bacteria, etc., than are the intermediate compounds produced by partial hydrolysis.

SUMMARY.

The base goods used as a type of processed fertilizers is an organic nitrogenous fertilizer which contains acid phosphate. This product is produced by the action of sulphuric acid on certain trade wastes; the heat is generated by the interaction of the acid with the organic wastes and rock phosphate in the course of the manufacture of acid phosphate. It is here shown that the hydrolysis of the protein is almost complete, the nitrogenous compounds in the finished fertilizer being principally the products of primary protein decomposition, together with a small amount of a proteoselike compound which has persisted.

From the sample of base goods were isolated the following nitrogenous compounds, two purine bases, guanine and hypoxanthine; the three diamino acids, arginine, histidine, and lysine; and two monoamino acids, leucine and tyrosine. A proteoselike compound was also obtained and its general nature established.

By means of the Van Slyke method the approximate proportions of the different forms of nitrogen contained in the fertilizer were

estimated, and the extent of the hydrolysis of the original proteins was determined. It was also shown by this method that the proteose-like compound was composed of acid amide radicals, diamino acid radicals, especially lysine, and monoamino acid radicals, particularly the monoamino acids which contain non-amino nitrogen.

The question of the availability of nitrogen is discussed and from a consideration of the amount and the physiological action on plants of the different forms of nitrogen present in the fertilizer it is concluded that the water soluble nitrogen of this fertilizer should have an availability equal to or greater than the nitrogen of dried blood, or other high-grade fertilizers. These results are in accord with the results obtained by the plant method of determining availability.

The general chemical principle which underlies the method for rendering available the nitrogen contained in most trade wastes, which are to be used as fertilizing materials, is shown to be either partial or complete hydrolysis of the protein of the wastes by any suitable means.

The more complete the hydrolysis the more available the nitrogen in the fertilizer becomes, since the products of complete hydrolysis of proteins are not only utilized by the plants themselves as nutrients but they are more easily ammonified when placed in the soil than are the more complex compounds, such as peptones, proteoses, and the proteins themselves.

This investigation aims only at an explanation and exposition of the general chemical principles involved in the treatment of trade wastes and other organic material to render the nitrogen contained therein more available for agricultural purposes. It does not aim to present the research methods here employed as general methods for analyzing such fertilizers, nor can the quantitative figures obtained be expected to apply to all products of similar manufacture, for the reason that the different kinds of nitrogen compounds will necessarily show different proportions according to the nature of the materials which enter into the mixture.

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SOILS OF THE SASSAFRAS SERIES.

By J. A. Bonsteel,
Scientist in Soil Survey.

DEFINITION OF THE SERIES.

The soils of the Sassafras series are distinguished by the characteristic brown or yellowish-brown color of the surface soils and by the yellow or reddish-yellow color of the subsoil. At depths ranging from 2 to 3 feet the deeper subsoil is frequently sufficiently tinged with red to become a pale orange. In the dry condition both the surface soils and subsoils of the more sandy members of the series are decidedly yellow, but when moist the deeper brown shade is usually developed. A fresh cut in the subsoil of practically every member of the series will usually show a distinct reddish coloration below a depth of 2 feet.

Practically all of the typical occurrences of the soils of the Sassafras series show the existence either of a distinct bed of medium to coarse gravel or of fine gravel mixed with coarse and medium sand at depths which range from 2½ to 5 feet. In the case of large areas of the Sassafras silt loam the underlying gravel bed is covered to a depth of 8 to 10 feet by the heavy, compact, silty loam soil and subsoil. It is generally true that the gravel is coarser and the beds are more continuous and thicker near the inland border of the region where these soils are found, becoming thinner and grading into fine gravel and coarse sand as the seaward margin of the various types is approached.

In certain localities, as on Long Island, along the lower courses of the Delaware River, and opposite the mouth of the Susquehanna River, large blocks of stone or bowlders derived from various formations of the Appalachian and Piedmont regions are found within the underlying gravels or scattered sparingly over the surface of the different soil types. Otherwise the different soils of the series are characteristically stone-free.

All of the different types consist of water-laid materials, chiefly formed as marine, estuarine, and fluvial terraces, although some of

the areas consist of closely related outwash material deposited in connection with the glaciation of the Long Island area and others seem to be derived from older coastal plain deposits. The materials entering into the formation of the soils of the Sassafras series have been derived from the Appalachian Region, the Piedmont Plateau, from glaciated areas immediately to the north of the principal areas of their occurrence, and from the underlying Coastal Plain deposits reworked in some cases. The latter materials are dominant in the sections nearest to tidewater while the mingling of materials from other sources is more pronounced along the inland border of the general region in which these soils occur.

The soils of the Sassafras series are distinguished from those of the Norfolk series by the predominant gray color of the surface soils and the yellow color of the subsoils of the latter series and by the reddish color and presence of the underlying beds of gravel or coarse sand in the case of practically all areas of the Sassafras soils.

The soils of the Elkton series, which are found closely associated with those of the Sassafras series, are marked by the gray color of the surface soils and the mottling of yellow and gray in the subsoils. They are characteristically not so well drained as the soils of the Sassafras series.

The soils of the Portsmouth series, which are also associated with those of the Sassafras series, are distinctly dark gray to almost black at the surface and light gray in the subsoils. They are always poorly drained in their natural state.

The soils of the Collington series are darker in color at the surface and usually show a greenish tinge, due to the presence of greensand marl in the subsoil.

GEOGRAPHICAL DISTRIBUTION.

The soils of the Sassafras series are confined to the northern portion of the Atlantic Coastal Plain. (See fig. 1.) Considerable areas of the soils of this series have been mapped in the central and western portions of Long Island. A broad belt of soils classed with the series has been found to extend through central New Jersey from the vicinity of New Brunswick southwestward to the region around Camden and thence southward along the Delaware River and Delaware Bay to Bridgeton, N. J. This belt is interrupted by occurrences of other Coastal Plain soils, and is more nearly continuous after the Delaware drainage area is reached. The same general area is continued west of the Delaware by narrow areas along the river in the extreme southeastern part of Pennsylvania.

A large part of northern and central Delaware from the vicinity of Wilmington to that of Dover is occupied by the different soils

of this series, while considerable areas of some of the types are found thence southward to the Virginia counties east of Chesapeake Bay.

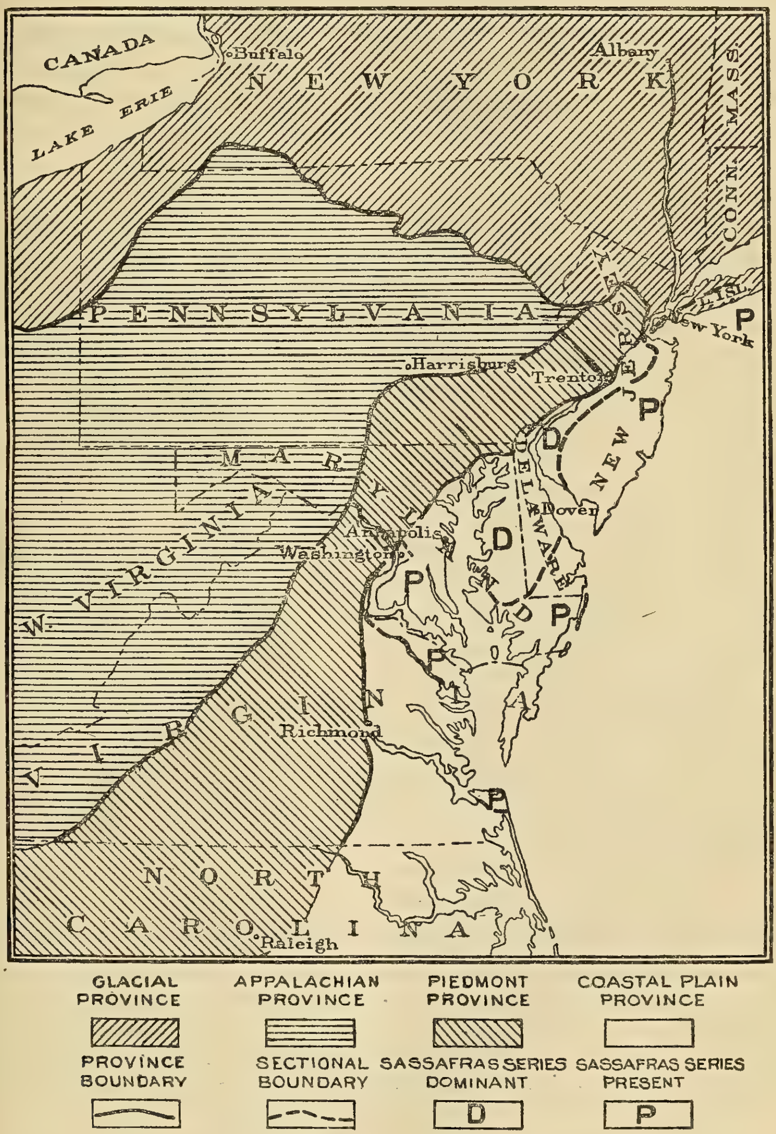


Fig. 1.—Soils of the Sassafras series.

The soils of the Sassafras series are extensively developed in the eastern counties of Maryland from the mouth of the Susquehanna River to the Delaware line and southward. In these counties, also,

other soil series become more extensive toward the south. The soils of the Sassafras series, however, dominate in area all the Maryland-Delaware Peninsula from the head of Chesapeake Bay to the latitude of the southern boundary of Delaware.

To the west of Chesapeake Bay, in the Maryland counties which lie between the bay and the Potomac River, the soils of this series are found in considerable area although they do not dominate the section. They are principally found along the lower forelands and terraces which border the bay and along the estuarine rivers which empty into it, although some areas also extend across the lower divides separating these waterways.

South of the Potomac River the soils of the Sassafras series are chiefly confined to low terraces along the tidewater estuaries and to the low divide separating the Potomac and Rappahannock River drainages. The soils have not been mapped in detail in any of this territory. A small area of one type has been found in the vicinity of Norfolk, Va. It is not believed that any large areas of the Sassafras soils will be found south of the Rappahannock River, since the materials and manner of derivation of more southern Coastal Plain soils would not be expected to give rise to soils of this class.

It will be seen that the total area within which the soils of the Sassafras series have been encountered is restricted to an elongated oval whose broader southern extremity lies approximately in latitude 37° N., and its narrow northern extremity is found upon Long Island in latitude 41° N.

The extreme length of this region from northeast to southwest is approximately 300 miles, while the extreme breadth, in the latitude of Washington, D. C., is a little over 100 miles.

Within the region outlined, the soils of the Sassafras series occupy approximately one-third of western Long Island; one-half of the Coastal Plain portion of the soil survey of the Trenton area, New Jersey; nearly three-fourths of the area included in the soil survey around Salem, N. J.; from 50 to 80 per cent of the various soil surveys in the Coastal Plain region of the Maryland-Delaware Peninsula as far south as the southern line of Delaware; only about one-fourth of the soil survey area of Worcester County, Md.; more than one-half of the soil survey of Anne Arundel County, Md.; and from 15 to 25 per cent of the areas which have been surveyed south of this county and on the western side of Chesapeake Bay.

THE NORTH ATLANTIC COASTAL PLAIN.

The northern part of the Atlantic Coastal Plain consists of a low-lying, gently sloping region which intervenes between the coast line and the more elevated interior. It is only within the portion of this physical division which extends from the southern end of Chesa-

peake Bay to the western end of Long Island, N. Y., that the soils of the Sassafras series have been encountered.

In general, the coast is fringed by long, narrow stretches of Coastal beach between which and the main land there are included narrow sounds and bays and stretches of Tidal marsh. The main land rises gently inland through the greater part of the coast country, although low coastal bluffs are locally found and the Navesink Highlands, with an elevation of 276 feet, approach within a mile of the shore line in east-central New Jersey. Elsewhere the rise toward the interior is gentle and for the first few miles does not usually exceed 5 feet to the mile. Near the interior margin the rate of slope rapidly increases to 10 or even 20 feet per mile. From the vicinity of Raritan Bay to the Delaware River and thence near the inner line of the Coastal Plain as far as the Potomac River there is a sharp slope toward the interior and the main body of the Coastal Plain is separated from the Piedmont Plateau and from other Coastal Plain deposits along its front by an irregular valley. The general trend and extent of this depression is outlined by the direction of the Pennsylvania and the Baltimore & Ohio Railroads, which follow it from Newark, N. J., to Washington, D. C. In part this valley is a land feature, as across central New Jersey and from Baltimore to Washington, but in part it has been occupied by estuarine waters as along the Delaware River from Trenton to Salem, N. J., around the headwaters of Chesapeake Bay, and in the westward bend of the Potomac River immediately south of Washington, D. C.

From the vicinity of Fredericksburg, Va., southward this valley feature is lacking and the elevated interior margin of the Coastal Plain directly overlaps the Piedmont Plateau.

Within this northern section of the Atlantic Coastal Plain there are four subdivisions which possess different details of elevation and relief.

The portion which lies west of the Chesapeake Bay, from the James River to the mouth of the Susquehanna River, consists of an elevated inner section of the Coastal Plain, which is deeply dissected by broad estuarine stream valleys. Both in eastern Virginia and in the southern counties of Maryland the remnant of the higher portions of the Plain takes the form of narrow or broad plateaulike ridges, which are locally known as "river necks." These have an elevation of 100 to 250 feet along the inner edge of the region, but their axes sink gradually toward Chesapeake Bay until they are terminated by a low escarpment or end in wave-cut cliffs along the bay shore. The larger estuarine rivers within this section are usually bordered on one or both sides by low-lying terraces. The lowest terrace rises from the water as a gentle slope or is bordered

by a low cliff. Thence its surface rises very gently, seeming almost a plain, to an inner escarpment, whose base is 30 to 40 feet above tide level. Frequently another terrace intervenes, at an altitude of 50 to 80 feet, between the lowest terrace and the inner plateau. In fact, the entire section consists of a series of steplike terraces rising from tide water to the general level of the upland except where wave or river cutting has destroyed the lower terrace forms. Such terracing is shown in Plate I, figure 1.

The section lying between the Chesapeake Bay and Delaware Bay, generally known as the Maryland-Delaware peninsula, possesses somewhat different topographic forms. The eastern shore of Chesapeake Bay from near the mouth of the Sassafras River, southward, is bordered by a tract of low land which corresponds in elevation with the lowest of the terraces on the western side of the bay. This swings eastward and forms the greater part of the peninsula south of the Delaware State line including, also, the southeastern portion of Sussex County, Del. It forms the lower portion of both shores of Delaware Bay and Delaware River as far north as Trenton. It is probably represented along the Atlantic coast of New Jersey by the belt of lowland, extending from Cape May nearly to the Navesink Highlands.

Along the eastern shore of Chesapeake Bay this lower terrace is bounded, inland, by a low escarpment which extends from near the mouth of the Sassafras River southward past Easton, Md., to the mouth of the Choptank River. Between this low ridge and the shore of Delaware Bay the higher terrace stretches as a gently undulating to nearly level upland. The highest elevations are found in the western portions of Cecil and Kent Counties, Md., where altitudes of 80 to 100 feet are attained. From these the general slope is gently seaward.

In southern New Jersey the surface features are somewhat different. As has been indicated, the lowest terrace of the Chesapeake Bay region extends along both shores of the Delaware River and Bay as a distinct topographic feature. It is possibly found along the Atlantic coast in the form of the low slope which rises from tidewater to an elevation of about 50 feet. In New Jersey the marked topographic feature of the Coastal Plain is formed by the ridge of dissected hills which extends from the Navesink Highlands on the northeast to the vicinity of Bridgeton, N. J., on the southwest. From this ridge the land surface declines rather rapidly toward the interior valley, separating the Coastal Plain from the Piedmont Plateau. The descent toward the sea is long and gentle in extreme southern New Jersey but short and steep as the eastern end of the ridge is reached in the Navesink Highlands.

On the western end of Long Island, N. Y., the narrow belt of Coastal Plain rises rather steeply from the coast line to the front of the ridge which forms the northern border of the island. The plain terminates against the front of this ridge at elevations of 100 to 240 feet above tide level. Within this sloping plain there are also outlying hills and ridges, consisting of old glacial moraine, which rise to considerable elevations above the surrounding surface. These roughly divide the plains into a higher interior plain and a lower coastal slope. These coalesce through intervals in the ridge. Otherwise the plain is interrupted only by shallow stream channels which are normally dry during a greater portion of the year.

The materials which constitute the older deposits of the North Atlantic Coastal Plain are chiefly unconsolidated gravel, sands, loams, clays, and marls, although there are local occurrences of indurated clays and iron-cemented sands and gravels of little thickness and of limited extent.

These sediments of varying degrees of coarseness have been derived from the adjacent, interior land areas, transported to the older shore lines, and deposited at various periods of geologic time as successive layers or strata in the older marine or estuarine waters. The surfaces of all of these older deposits are marked by a seaward slope and the oldest formations reach the surface along the inner margin of the Coastal Plain while the younger ones are successively encountered at or near the surface in a seaward direction. These older formations, from the Cretaceous to the Miocene in geologic age, form the basal structure of the Coastal Plain. They reach the surface chiefly along the lines of greatest erosion near the inner margin of the region and they are very extensively covered by later deposits, forming the terraces and the greater part of the seaward slopes of the present land surfaces. These later deposits are referred by geologists to the Pliocene and Pleistocene periods. They immediately preceded the present geologic time.

The soils of the Sassafras series are chiefly derived from the deposits of the Pleistocene age. This is the latest completed geologic period before the present time. It was marked in the northern portion of the area under discussion by two or more invasions of glacial ice. During the period of ice occupation, and particularly while the ice sheet was melting and its front receding, large amounts of material were deposited near its front in the form of glacial outwash. At the same time other glacial material was carried down all of the larger streams of the region to be deposited as a part of the material of the Pleistocene terraces, which were being formed at the same time along the coast.

Even the streams considerably to the south of the region directly affected by glaciation were considerably swollen and their courses were blocked by river ice during portions of the year. This gave rise to the transportation of considerable amounts of coarse gravel, and even of stones of large size, which were carried in floating ice. When the ice melted along the coast or in the estuarine waters this coarser material was mingled with the finer grained sediments brought under normal conditions of erosion and transportation. Thus the Pleistocene sediments along the margin of the glaciated region, and even to a considerable distance to the south, have been directly or indirectly influenced by the glaciation of the more northern region.

Long Island, N. Y., lies within that portion of the region which was directly invaded by the ice during the glacial period.[1] As a result all of the older formations were overridden by the sheet of glacial ice, which advanced at one time as far south as the line of hills that extends from the vicinity of Westbury to Montauk Point. These hills represent the deposition of material as a terminal moraine while the ice stood along this line. Later the glacial ice receded and then readvanced to a position along the more northern belt of hilly territory, which follows the northern shore of the island, where additional morainal material was deposited. At the time of this halting there was spread out over all of the southern portion of the island the thin sheet of gravelly, sandy, and loamy material which constitutes the present surface of the land. The sloping plains which intervene between the two lines of morainal hills and which sink below the water level along the southern shore of the island were formed at that time by the deposition of material partly transported by the ice from mainland to the north and partly derived from the older formations, which formed the surface upon which the ice rested.

A large part of this deposition took the form of cross-bedded sands and gravels and of rather coarse sand, washed out by water from the melting ice. Where these coarser materials form the present land surface they give rise to the areas of Sassafras sand as mapped upon the western end of Long Island. The higher, interior plain and a large part of the marginal plain which intervenes between the northern hills and the south shore west of Farmingdale are occupied by a gravelly silty loam formed at a late stage of the deposition of this material. This gives rise to the extensive areas of the Sassafras gravelly loam mapped there. Small areas of loamy material were deposited immediately to the West of Jamaica Bay. This forms the Sassafras loam. A large part of the material built into these deposits is undoubtedly of direct glacial origin.

[1] Professional Paper No. 82, U. S. Geol. Survey. The Geology of Long Island, N. Y., by M. L. Fuller.

It is certain that the Delaware River carried a large amount of material from the glaciated area around its headwaters to its submerged lower course, thus contributing glacial material to the marine and estuarine sediments which were being formed along the coast line.

The Susquehanna River was also affected by glaciation along its upper courses and carried glacial material in some volume to be contributed to the deposits near its mouth.

While the rivers farther to the south had no direct connection with the glaciated area, yet conditions of erosion and transportation were so affected that large amounts of the fine-earth materials from the Appalachian and Piedmont sections were carried seaward and deposited through the Chesapeake Bay region. With these finer sediments small amounts of coarse material in the form of gravel and large blocks of stone were transported and deposited. The latter constitute the only direct evidence of the changed climatic conditions since they were evidently carried within or upon floating masses of ice of considerable size.

To the west and south of the mouth of the Hudson River the land area which now constitutes the surface of the Coastal Plain was formed at different stages of submergence and emergence, chiefly in the form of successive terraces. It is probable that each of the different terraces represents a period of submergence of the land area followed by emergence. In general the oldest terrace at present occupies the highest elevation and each younger terrace is found at successively lower elevations.

The different terraces are developed to very unequal extents in the different portions of the North Atlantic Coastal Plain from southern New Jersey to tidewater Virginia.

In New Jersey the terrace-form development of the later Coastal Plain deposits is generally indistinct except in the case of the latest and lowest terrace. This has been called the Cape May formation by the New Jersey Geological Survey.[1] It fringes the Atlantic coast in a narrow border rising from sea level to about 50 feet in elevation. Its chief development is found from Cape May northward along the Delaware Bay and River to the vicinity of Trenton, N. J., where its deposits merge with those brought down by the river from the glaciated region to the north. From this circumstance it can be correlated with the latest glaciation of the more northern region.

Along the water front the elevation of this terrace varies from marshy stretches at tide level to low cliffs of 5 to 10 feet in height. The land surface of the main portion of the terrace is nearly level

[1] See N. J. Geol. Survey Ann. Rept. 1898, and Trenton and Philadelphia Folios, U. S. Geological Survey.

although streams have cut shallow channels within the terrace and low ridges and swells give a slightly undulating character to the surface. There is normally a gentle rise toward the interior and the landward margin of the terrace along the Delaware River side is marked by a sharp rise or by steeper slopes. In the Atlantic coast portion of southern New Jersey this interior escarpment is not marked or may be entirely lacking. In the Delaware Valley phase of this formation the upper level of its deposits lies between 35 and 50 feet above sea level. The interior margin of this formation is frequently bordered by delta deposits accumulated where the larger streams brought other Coastal Plain material to the shore of the estuary which was formed along the Delaware embayment. These are usually sandy and gravelly in their character. They have been derived from several of the older Coastal Plain deposits. Within the level area of the Cape May terrace the materials consist chiefly of gravel, sand, and loam, with small areas of stiff clay in some localities. These materials have been derived both from the other Coastal Plain deposits and from the glacial material which was brought down by the Delaware River. There has also been a considerable contribution of wind-blown sand which was either spread out as a thin sheet over the surface of the water-laid deposits or even heaped into low mounds and ridges.

In general the surface material of the Cape May formation is rather sandy and the soils which are derived from it consist largely of the Sassafras sand, fine sand, and fine sandy loam. The Sassafras silt loam is also developed to quite an extent in some parts of the formation, notably near Salem, N. J. Even the level areas of the Sassafras sand and fine sand are frequently underlain by this heavier material and in some localities by Miocene and Cretaceous clays, and it is probable that in such situations they constitute a surface deposit of wind-transported material laid down over the older sediments.

The next higher and older formation of Pleistocene age in southern New Jersey has been called the Pensauken by the New Jersey Geological Survey. It occupies elevations from about 50 feet above tide level to an altitude of more than 200 feet in different parts of the Coastal Plain. The Pensauken formation is most extensively developed along the flanks of the Delaware Valley and on the slope from the Coastal Plain toward the Piedmont Plateau between Trenton and New Brunswick. Considerable areas are also found on the slope between the high ridge within the Coastal Plain and the margin of the Cape May formation along the Atlantic.

The Pensauken formation is chiefly made up of cross-bedded gravel and sand having a thickness ranging from 2 or 3 to 50 feet. Over some portions of this coarser material there has been deposited

a thin layer of silty loam, which is not considered as an essential part of the formation by the New Jersey Geological Survey. It is very similar to the heavier loam found in the Cape May formation and gives rise to the same soil type, the Sassafras silt loam. The coarser materials of the Pensauken formation give rise to the gravelly and sandy members of the Sassafras series. The soils of this series are thus found in almost continuous development from near tide level in the Cape May formation to altitudes of 150 to 200 feet in the area covered by the Pensauken formation.

It is worthy of note that the soils of the Sassafras series have been encountered in their widest development in the State of New Jersey within the Delaware Valley and upon the slopes of the valley which separates the main body of the Coastal Plain from the Piedmont Plateau. These soils thus occupy a position where their materials were affected during deposition by contributions from the glaciated area immediately to the north. They may consist, in any one locality, of material largely derived from older, underlying Coastal Plain formations, but where typically developed there is usually evidence that the glaciation to the north contributed a considerable amount of both fine and coarse material while a still larger amount was originally derived from both the Piedmont and Appalachian regions.

The oldest deposits of the Pleistocene age in the New Jersey portion of the Coastal Plain are called the Bridgeton formation by the New Jersey Geological Survey. They cap the higher hills in southern New Jersey above an elevation of about 150 feet. The materials are largely gravel and sand, although large bowlders give evidence that this formation was also affected by the earlier glaciation of the land areas to the north. It is probable that this formation gives rise to considerable areas which will be correlated with the soils of the Sassafras series.

Areas of the different soils of this series are also found to coincide closely with the portions of these three terraces found on the western side of the Delaware River in the extreme southeastern part of Pennsylvania.

In the Maryland-Delaware Peninsula the terrace form of the deposits of Pleistocene age is marked and three terraces have been identified by the Maryland Geological Survey.[1] The lowest and youngest of these terraces has been called the Talbot formation within this State. It is continuous with the Cape May terrace of the New Jersey Geological Survey and can be directly correlated with it. It forms a low, nearly level terrace along the entire eastern boundary of Delaware, narrow in the northern part and broadening to a width

[1] See Maryland Geol. Survey, "Pliocene and Pleistocene," and Dover Folio, U. S. Geological Survey.

of 15 or 16 miles in southern Delaware, and completely occupying the greater part of the peninsula south of the Delaware State line. Thence it is developed as a broad, low-lying plain along the southern part of the eastern shore of Chesapeake Bay as far north as the mouth of the Choptank River. From this vicinity to the mouth of the Sassafras River it becomes narrower but occupies all of the forelands and islands. North of the Sassafras River to the head of Chesapeake Bay it is but sparingly represented by lowlands along the water front.

Throughout the peninsula the Talbot (Cape May) terrace rises gently from the water level either with a low slope or by a low wave-cut scarp. Its surface is a very gently sloping plain, which is chiefly relieved by the tidewater channels of streams which cross it and by low ridges which merely serve to render the surface gently undulating. The terrace is continued for some distance up the channels of the estuarine rivers which are the chief tributaries of the Chesapeake Bay from the eastern shore.

The portion of the Talbot terrace which lies along the Delaware Valley and the Atlantic Ocean rises to an altitude of about 45 feet above sea level, where it merges into the next higher terrace, usually without any marked topographic break. At most a low slope or scarp may occur locally. On the side toward Chesapeake Bay the inner margin of the terrace is much more sharply marked by a low scarp of 10 to 25 feet in elevation, which extends interruptedly from near the mouth of the Choptank River to the mouth of the Sassafras River. The Talbot terrace is also extensively developed as a low front land along the western shore of the Chesapeake Bay from the mouth of the Susquehanna River to the mouth of the Patapsco River.

The materials which enter into the structure of the Talbot terrace are all unconsolidated and consist of gravel, sand, loam, and some areas of clay. It is probable that a large part of this material was brought to its present position from the Piedmont and Appalachian regions by the Delaware and Susquehanna Rivers. The presence of large ice-borne blocks from both of these regions is noticeable along the upper waters of Chesapeake Bay and even some of the finer material bears close resemblance to the existing surface materials in the adjacent Piedmont region. There can be little doubt that the Talbot formation of Maryland and the Cape May formation of New Jersey are one in origin and mode of formation, and it is probable that both are of about the same age as the youngest glacial material found upon the western end of Long Island.

The Talbot formation contains large areas of soils which have been correlated with those of the Sassafras series. The areas of Sassafras sand and loamy sand along many of the estuarine embayments of the Maryland-Delaware Peninsula and the Sassafras sandy

loam, loam, and silt loam of the better-drained portions of this formation all cover large areas.

The next higher and older terrace of the Pleistocene is known as the Wicomico formation in Maryland. Within the peninsula it occupies all of the higher interior portion from a line drawn between Wilmington, Del., and Elkton, Md., southward a little beyond the southern line of Delaware.

As has been noted, it is separated from the Talbot terrace only by low slopes or indistinct scarps on the seaward side. Thence its surface rises gently nearly to the eastern shore of Chesapeake Bay, but sinks sharply to the surface of the Talbot formation or to the waters of the bay along its western margin. A few small remnants of this terrace are also found along the steeply sloping boundary between the Piedmont and Coastal Plain from the vicinity of Wilmington to that of Baltimore.

The materials which constitute the Wicomico formation in this section consist chiefly of bowlders,, gravel, sand, and loam. The coarser materials are generally found at the base of the formation, and these are usually overlain by either a sandy loam or a rather heavy silty loam surface deposit. Generally the gravel constitutes a basal stratum rather sharply bounded by the underlying materials of various older formations, while it grades upward into the loamy covering which forms the Sassafras loam and silt loam. The slopes, where somewhat eroded, give rise to a mingling of the loam with underlying gravel, forming the Sassafras gravelly loam. Around the head of Chesapeake Bay some areas of the Sassafras sand are found within the limits of this formation.

The highest Pleistocene terrace is represented on the Maryland-Delaware Peninsula only by fragments, which are found along the ridge of high land on Elk Neck and to a limited degree along the steep slope which marks the inner border of the Coastal Plain around the mouth of the Susquehanna River. This highest Pleistocene terrace is called the Sunderland formation by the Maryland Geological Survey. A small portion of its surface is composed of materials giving rise to the Sassafras silt loam.

The Maryland-Delaware Peninsula constitutes the region within which the soils of the Sassafras series are most widespread. They are found at all elevations from the vicinity of tide level to altitudes of more than 100 feet, while small remnants occur along the inner margin of the Coastal Plain at elevations up to 240 feet.

The materials which give rise to these soils consist of a mingling of earthy matter from the Appalachian region and the Piedmont Plateau with other materials derived from the underlying and older Coastal Plain formations. In general, the coarser gravel and sandy

materials form a basal bed underlying loam or silt loam coverings, although extensive areas of sandy surface material are found along the estuarine rivers of the section and within the seaward margin of the Talbot formation.

The influence of glaciation to the north is shown by the presence of large ice-borne blocks within all parts of the terrace formations.

The Talbot terrace is continued to the west of Chesapeake Bay in the peninsula lying between the bay and the Potomac River. This region is locally known as southern Maryland.[1] The lowest terrace is fairly well developed from Baltimore south to the northern end of Calvert County, Md., as a gently sloping front land rising from water level to an altitude of 40 or 50 feet. Its shore line is either low or defined by a wave-cut cliff of a few feet in height. The terrace itself constitutes a slightly relieved plain with a gentle slope toward tide water. From this region south to the mouth of the Patuxent River it is almost entirely wanting, having been cut away by the active erosion of the waters of Chesapeake Bay.

It is again developed along both shores of the Patuxent River to a limited degree and much more extensively along the shores of the estuarine portion of the Potomac River. In all of these localities it forms the low front lands interruptedly bordering these estuaries.

The origin of the materials of the Talbot formation in southern Maryland is approximately the same as upon the Maryland-Delaware Peninsula, although a larger proportion of material derived from older Coastal Plain formation is incorporated. The succession of materials is about the same and the base is marked by gravels and coarse sand, while the present surface is formed by silt loam, loam, and rather fine sandy coverings. Wherever this formation is well drained, considerable areas of the Sassafras soils are encountered.

The next higher terrace, the Wicomico, is rather sparingly developed in southern Maryland. It occurs at elevations ranging from 50 to 80 feet in the estuarine valleys and along the bay shore. Its surface also rises with the gradient of some of the tributary streams until elevations of 100 feet are attained near the Piedmont border.

In general the surface of the Wicomico terrace is separated from both the Talbot and Sunderland terraces by a distinct scarp. In some instances the narrow remnants of the formation have been so eroded that neither the flat surface nor the bounding scarps may be readily distinguished. In almost all instances this formation occurs as narrow, fragmentary benches of small area in this section of the Coastal Plain.

The materials entering into the composition of the Wicomico terrace are chiefly gravel, sand, and the capping of loam or silt loam,

[1] See Patuxent, St. Marys, and Nomini Folios, U. S. Geol. Survey.

which is characteristic of this formation east of the Chesapeake Bay. The chief areas of the Sassafras silt loam found in southern Maryland occur upon its surface.

The highest Pleistocene terrace in southern Maryland is called the Sunderland formation. It occupies a large part of the broad, nearly flat interstream areas, especially along the Chesapeake Bay and the lower reaches of the Potomac River. It is in reality a gently sloping plain which has been dissected into broad, irregular plateaus, separated by the present tidewater estuaries.

A considerable proportion of the area of the Sunderland formation in southern Maryland consists of materials that do not give rise to soils of the Sassafras series. The heavy, silty soil of gray color which predominates on the plateau surface is classed as the Leonardtown loam. Upon somewhat more rolling surfaces and along certain of the uplands there are found soft sandy loams and fine sands derived from this formation and formed by its partial erosion and mingling with underlying materials which have been correlated as the Sassafras sand, fine sand, fine sandy loam, and loam. These areas are of somewhat mixed origin, but owe their chief characteristics to the influence of the material derived from the Sunderland formation.

A large area in the northern part of southern Maryland is occupied by the highest Coastal Plain terrace, referred to the Lafayette formation, and by the exposed outcrops of some of the older Coastal Plain strata. None of these give rise to soils of the Sassafras series.

All the occurrences of the soil of the Sassafras series in southern Maryland are confined to the areas of the Pleistocene terraces, except where erosion has partially removed these formations and mingled their remnants with older materials. The largest areas of the soils of this series are found along the upper waters of Chesapeake Bay and along the forelands which border the principal estuarine rivers, particularly the Potomac. Only the better-drained areas of these terraces give rise to soils of this series.

Examinations of the soil materials of the region south of the Potomac River show that the Potomac and the Rappahannock Rivers are discontinuously bordered by the lowest terrace, known as the Talbot formation[1] in Maryland. It is also evident that the Wicomico terrace is represented at intermediate elevations and that the rolling or flat-topped interstream areas belong in part to the Lafayette formation.

These different formations are closely related to the similar occurrences in southern Maryland, and soils referable to the Sassafras series occur to a limited extent along the low forelands upon the lower courses of the rivers. Considerable areas of the Sassafras loam and

[1] See Nomini and Fredericksburg folios, U. S. Geol. Survey, and Bul. IV, Virginia Geol. Survey, Physiography and Geology of the Coastal Plain Province of Virginia.

silt loam are also known to exist upon the low flat-topped divide between the Potomac River and the Rappahannock River, at least as far inland as the western boundary of Westmoreland County, Va. Farther to the south, in tidewater Virginia, other soil series occupy both the terraces and the interstream divides. These have been classed as the soils of the Wickham and Norfolk series.

A small area of the Sassafras sandy loam has been mapped on the low terrace formed by the Talbot formation between Norfolk, Va., and the Atlantic coast.

It will be seen that the various soils classed in the Sassafras series may, almost without exception, be referred to formations of Pleistocene age in the northern portion of the Atlantic Coastal Plain. In the extreme northern portion of this section the relation of these soils to glaciation is direct. Farther to the south and west this relationship is chiefly shown by the presence of limited amounts of ice-borne material mixed with the materials brought in from the Appalachian and Piedmont regions and with material derived from the older formations of the Coastal Plain. These have been deposited as a series of marine, estuarine, and fluvial terraces which constitute the low-lying section between the coast line and the more elevated land to the interior.

While the soils of the Sassafras series do not occupy the entire extent of these geological formations they are quite generally found along the interior margin where the glacial material and the fine earth from Piedmont and Appalachian sources were mingled with sediments derived from the older Coastal Plain deposits.

All these classes of soil-forming material were sorted and rearranged during the processes of transportation and deposited so that the coarser materials are most frequently found at the base while the surface materials may range from heavy silt loam to medium sand.

Only the well-drained portions of the different terraces are occupied by soils of the Sassafras series. Less well-drained areas give rise to soils classed in the Portsmouth or Elkton series.

The area of material referable to the soils of the Sassafras series is usually greatest in positions around the mouths of streams which issued from the glaciated areas to the north or whose headwaters were affected by glaciation. As the terraces are followed to the west and south other soil materials become predominant, and the higher terraces are occupied by soils of the Norfolk, Leonardtown, and Wickham series.

SASSAFRAS SAND.

Considerable areas of the Sassafras sand have been mapped in the soil surveys of western Long Island, the Delaware River section of New Jersey, in the Maryland-Delaware peninsula, and in the southern Maryland counties lying between the Chesapeake Bay and the

FIG. 1.—WHEAT ON THE SASSAFRAS LOAM, WICOMICO TERRACE, IN SOUTHERN MARYLAND.

FIG. 2.—RYE ON THE SASSAFRAS SAND, CAROLINE COUNTY, MD.

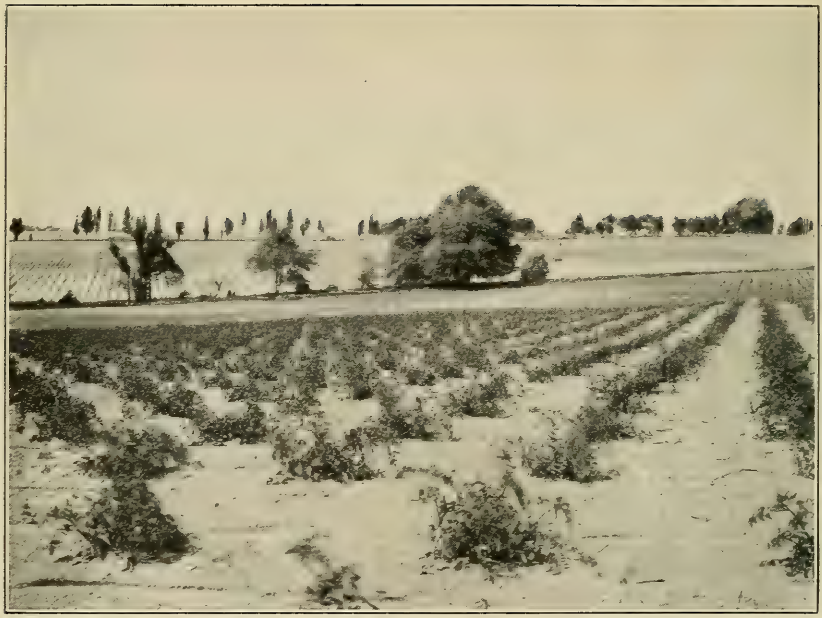


FIG. 1.—EARLY TOMATO CROP ON SASSAFRAS SAND, SOUTHWESTERN NEW JERSEY. OTHER TRUCK CROPS IN THE BACKGROUND.

FIG. 2.—PICKING STRAWBERRIES, SASSAFRAS SAND IN SOUTHWESTERN NEW JERSEY.

Potomac River.[1] A total area of 337,346 acres has been mapped in these various surveys. It is probable that the entire geographic range of the type has been outlined, but the total area of this soil is undoubtedly considerably greater than the area already included within the limits of the soil surveys.

The surface soil of the Sassafras sand to an average depth of about 9 inches is a brown or reddish-brown, medium to coarse textured sand. Frequently the surface color may grade into yellow or gray tints and the texture is sometimes somewhat loamy, especially where a considerable amount of organic matter exists in the surface soil. The subsoil is most frequently a yellow or reddish-yellow sand, usually rather incoherent just below the surface soil, but becoming more loamy at a depth of 2 to 3 feet. Frequently the immediate subsoil is underlain at a depth of 3 feet by very coarse sand or by sand and gravel mixed. The deeper subsoil is also frequently tinged with red so as to become orange or brown in color.

In some areas small amounts of fine gravel are mingled with both the soil and subsoil, especially upon steep slopes, where erosion has exposed underlying beds of coarser material. In a few localities indurated, iron-cemented gravels give rise to plates and blocks of "ironstone," which appear most numerously upon slopes or where this soil type merely persists as a capping on partially eroded hills. Typically the surface soil is a uniform, medium sand in which the chief variations consist of more or less organic matter and in a slightly variable amount of the finer-grained soil particles.

The Sassafras sand is distinguishable from the Norfolk sand, with which it is sometimes associated, through the generally gray appearance of the surface soil and the yellow coloration of the subsoil of the latter.

The Sassafras sand occurs in quite a variety of topographic positions, but the greater part of the areas of the type thus far mapped is found upon gently sloping terrace plains or upon the slightly inclined surfaces of delta deposits. Within these areas there is usually a small percentage of the type which occupies the sloping sides of streamways or the marginal slopes of the deltas or terraces. In some instances, also, erosion has left small areas of the Sassafras sand as isolated cappings upon the higher hills. Areas of this character are liable to be rougher and more sloping than the characteristic occurrences of the type. The most extensive areas and those of the highest agricultural value exist as gently sloping plains and nearly level terrace areas. In such positions the level of the ground water is frequently near the surface of the land. This is the case along the southern shore of Long Island and along the low

[1] In some of the earlier surveys no distinction was made between the sand and fine sand, and both were mapped as Sassafras sand.

terraces which border the Delaware River and the banks of many of the estuarine streams of the Maryland-Delaware peninsula. This circumstance frequently modifies the natural moisture-holding capacity of the type and renders it capable of producing a wider range of crops than its rather coarse texture would seem to indicate.

Generally, the Sassafras sand is well drained, both on account of its sandy texture and because it is found in areas where stream drainage has been well established. The higher lying part of the type is even somewhat excessively drained and is therefore rather more limited in its crop uses than the lower lying areas of which mention has been made.

While there is thus some variation in the circumstances of attitude and of natural drainage within the total extent of the type, the Sassafras sand is generally level to gently undulating in its surface features, well drained to somewhat droughty, and usually rather restricted, because of these facts, in the character of crops which may successfully be grown upon it.

The extent to which the Sassafras sand has been occupied for agricultural purposes varies considerably with the geographical location of the different bodies of this soil. In all areas near to the great centers of population, such as the areas in central and western Long Island, those in central and southwestern New Jersey, and those in some parts of southern Maryland, the greater proportion of this soil has been cleared and placed under intensive forms of cultivation. In other regions more remote from the great markets for vegetable and fruit crops, and where the means for rapid transportation is lacking, considerable areas of the Sassafras sand remain in forest growth of pine and scrubby oak, or the areas are farmed with varying success for the production of the cereal grains, hay, and vegetables for home consumption. It is probable that 75 per cent of the type in the vicinity of the larger cities of the northern Atlantic coast is occupied for intensive forms of crop production, while diminishing percentages are utilized for any agricultural purpose in more remote locations. It may be roughly estimated that not more than one-half of the total area of the type thus far encountered in the soil surveys has been utilized for crop production. The development of the remaining areas will probably not occur until the use of such lands is made desirable by the extension of transportation facilities and an increased demand for the growing of special vegetable and fruit crops.

Because of the generally porous and unretentive character of both the soil and subsoil of the Sassafras sand, it is not found to attain to any high value for the production of the staple crops. In fact, in localities where such crops are the only ones whose production is attempted upon this soil, the yields obtained are usually below

the normal averages for the general region, and it is only where some unusual circumstance of saturated subsoil, seepage from higher lands, or the existence of a denser underlying loam or clay is of local influence that corn, the small grains, or the ordinary meadow grasses are grown to any marked advantage. This is so general that large areas of the Sassafras sand still remain in forest wherever local conditions do not favor special crop production.

Corn is more generally grown upon the Sassafras sand than any of the other cereals. The yields secured range from less than 20 bushels to 40 bushels per acre. The latter yields are only obtained in the seasons of heavy and well distributed rainfall, or upon portions of the type favored by an unusually high water table, the presence of retentive materials below the subsoil, or by specially good methods of soil management.

Wheat is locally grown on the Sassafras sand in some portions of Maryland. The yields are usually low, rarely exceeding 10 or 12 bushels per acre. The crop is not at all suited to such a porous soil, and is usually grown merely as a part of an established crop rotation.

Rye is grown to a limited extent and produces fair yields, ranging from 12 to 20 bushels per acre. It is probable that it is the small grain best suited to this soil. Where the straw can be sold to advantage, the growing of rye is more profitable than the growing of wheat. A good crop of rye grown on the Sassafras sand is shown in Plate I, figure 2.

Crimson clover is coming to be grown as a winter cover crop upon portions of the Sassafras sand along the Maryland-Delaware line. This crop not only gives an excellent winter growth for protective purposes, but it also is cut for hay at a time sufficiently early in the spring to permit of the planting of an intertilled crop for the summer season. It has also led to increased fertility of the Sassafras sand, where it has been used consistently. This is particularly the case where the crimson clover stubble or the remainder of the crop after it has been grazed during fall and spring is plowed under as a manure for the succeeding corn or tomato crop.

Cowpeas produce good yields of hay upon the Sassafras sand, and they are grown to an increasing extent as a summer hay crop. It has also been found that the peas may be produced for seed upon this soil, especially in the eastern counties of Maryland, and that the yield of seed constitutes a profitable cash crop, while the cowpea straw may be used as a valuable fodder.

None of the meadow grasses are grown to advantage upon the Sassafras sand, although a fair stand of red clover may be obtained for one year. Clover is sometimes seeded with the small acreage of wheat grown upon the type. The yields of hay are low.

While the Sassafras sand does not constitute a valuable soil for the production of the usual grain and hay crops, its warm, porous condition renders it an especially valuable soil for the growing of the special vegetable and small fruit crops.

Large areas of the type on western Long Island are located so close to New York City; other areas in central and southern New Jersey are so favorably situated near the Camden and Philadelphia markets; and even some areas in Maryland, located near to Baltimore, are so accessible to city markets that a considerable use is made of them in the production of small fruit and vegetables.

For the purposes of the market gardener and the trucker the Sassafras sand is a very valuable soil. Because of its coarse texture and through natural drainage, it is a warm, early soil, which may be worked at an early date in the spring and which forces the vegetables and fruits to a rapid growth and an early maturity. When heavily manured and properly managed, it gives satisfactory yields of a considerable number of such special crops. The type is recognized through extensive experience as one of the most desirable soils of the North Atlantic coast region for trucking and market gardening.

Added to the warm, well-drained character of the soil and the location of important areas of it near to market and to favorable transportation facilities is the fact that it lies at low elevations, and frequently within the protective climatic influences of large bodies of tidewater. This is the case with the areas found upon western Long Island; it is generally true of the most important areas in New Jersey; and it also applies to the areas of the type found near Baltimore, Md. These circumstances give rise to availability for crop uses early in the spring and to a lengthening of the growing season to such an extent that two or more crops are produced in one season from the same ground.

The vegetable crops grown upon the Sassafras sand frequently reach maturity at a date from four days to one week in advance of the same crops from the same localities grown upon other finer-grained and more retentive soils.

The Sassafras sand occupies the same relative position as an early truck crop soil in the northern Atlantic Coastal Plain that the Norfolk sand occupies in localities farther south. Both are the earliest soils of their respective regions.

A bewildering variety of vegetable crops is grown in rapid succession upon the Sassafras sand in all of the developed trucking sections of Long Island and southern New Jersey. No census statistics are available to give definite acreages of the different crops. In general it may be stated that early Irish potatoes, tomatoes, and sweet potatoes occupy the largest areas among these crops.

Upon western Long Island early Irish potatoes are the most extensive crop grown upon this type. The yields vary considerably under the management of different growers and under different seasonal conditions. It may be said that the high fertilization and careful cultivation given the crop usually result in yields ranging from 125 to 150 bushels per acre. The latter yield is sometimes exceeded. The early Irish potatoes grown upon the Sassafras sand in both New Jersey and upon Long Island are usually smooth, mealy tubers, which command a high market price. They reach the market in succession with the Irish potatoes grown in the Norfolk section, in the eastern shore counties of Virginia, and immediately after the crop from central Delaware. The New Jersey crop usually comes on the market in late July and early August, while the Long Island crop is marketed in greatest quantity from the latter part of August to early September. The crops grown upon other soil types in these same regions are usually a week or more later in date of maturity than the potatoes harvested from the Sassafras sand.

The Sassafras sand exerts a strong influence upon the production of sweet potatoes in New Jersey. From Trenton, N. J., southward to the vicinity of Bridgeton, N. J., extensive fields of sweet potatoes are annually grown. This is the northern limit of production for this crop upon any extended scale. It is only upon the more sandy and warmer soils that the crop is successfully produced in this latitude. Hence the Sassafras sand and the associated Sassafras fine sand come to be the chosen sweet-potato soils of the New Jersey growers.

The importance of the sweet-potato crop upon the Sassafras sand is clearly shown through the fact that 55 per cent of the total acreage in sweet potatoes and nearly 60 per cent of the total yield for the State of New Jersey are grown in the counties of Gloucester and Salem, largely upon this type and upon the Sassafras fine sand. The average yield of sweet potatoes for the State is approximately 142 bushels per acre, but the average yield from Gloucester County, which may be taken as representing very closely that of the Sassafras sand and fine sand, is in excess of 162 bushels per acre.

Both early Irish potatoes and sweet potatoes also constitute important crops upon the Sassafras sand in Anne Arundel County, Md.

Tomatoes, both for direct marketing and for the purpose of canning, are grown to some extent upon the Sassafras sand. In New Jersey the crop is chiefly grown for direct marketing as early in the season as possible. The soil type is conveniently located near to immediate markets and the tomatoes are frequently transported by wagon from the fields to the retail or wholesale markets of Camden and Philadelphia. A field of tomatoes on the Sassafras sand is shown in Plate II, figure 1.

Both in Anne Arundel County, Md., and in the Eastern Shore counties of Maryland tomatoes are extensively grown for the canning factories upon this and associated soil types.

The Sassafras sand is used to some extent for the growing of watermelons in both Gloucester and Salem Counties, N. J., where it is recognized as the soil best suited to this crop. Good yields of sweet, early melons are secured. Some melons are also grown upon the type in the different areas of its occurrence in Delaware and Maryland. Cantaloupes are less extensively grown than watermelons on this type, but give fair yields of melons of excellent quality.

For the production of extra early garden peas as a truck crop the Sassafras sand is only excelled by the Norfolk sand. In Anne Arundel County, Md., many acres of early peas are annually grown upon this soil. In the New Jersey trucking counties and upon Long Island early peas are also an important crop. In all of these localities string beans are grown to some extent. Both crops take a regular spring place in the succession cropping which marks the intensity of trucking methods, and it is a common sight to see the rows of peas and string beans so spaced that cucumbers or cantaloupes may be interplanted, making their growth and fully occupying the tract after the early peas and beans have been harvested.

There is probably no soil in the more northern trucking regions which is so well suited to the production of an extra early crop of asparagus as the Sassafras sand. The shoots are ready for cutting at an early date, they are easily harvested, and they are easily blanched to the creamy white demanded by certain markets. While asparagus is not grown in any large acreage upon the Sassafras sand yet the crop is one of high value, and it is very frequently found in small plots upon the market garden and truck farms located upon this soil type.

Numerous other truck crops are grown upon this soil. Among these may be enumerated eggplant, which is found to be well suited to this soil in the southwestern New Jersey counties; cucumbers, grown on Long Island, in New Jersey, and upon the Eastern Shore of Maryland; peppers, chiefly produced upon it in New Jersey; sweet corn, locally grown in small acreages upon many truck farms; and even extra early cabbage, carrots, turnips, beets, and spinach and kale.

The strawberry is the most widely grown and valuable small fruit produced upon the Sassafras sand. The type is chiefly used for growing such varieties as the Superior for early market and the Klondyke for midseason markets. The Gandy, a distinctly late berry, is grown only to a limited extent upon this soil. It is better suited to production upon the more loamy types of the Sassafras series and to the mucky, moist conditions of the Portsmouth loam

and sandy loam. Since these soils are commonly associated with the soils of the Sassafras series in the region of its most extended development on the Maryland-Delaware Peninsula, the later berries are decidedly restricted to these other types. A good field of strawberries on the Sassafras sand is shown in Plate II, figure 2.

Both dewberries and blackberries are planted successfully on the Sassafras sand. In Anne Arundel County, Md., the dewberry has become somewhat a specialty upon this soil.

In former years peaches were grown to quite an extent upon some portions of the Sassafras sand, but the crop is now of diminishing importance.

Early fall varieties of apples are grown upon it, but the Sassafras sand may not be considered as a type well suited to apple orcharding.

To summarize the uses of this soil type it may be said that the value of the special crops grown upon it in the various localities probably exceeds the value of the general farm crops produced, although the acreage is decidedly smaller. The type may be characterized as below the average in agricultural value for the production of the cereal grains and the common meadow grasses; fairly well suited to the growing of crimson clover and cowpeas; and especially well suited to the production of a wide variety of vegetables and small fruits where areas of the soil are conveniently situated with respect to transportation and market.

SASSAFRAS LOAMY SAND.

The Sassafras loamy sand has been mapped to a total extent of 57,024 acres, found chiefly in the Easton area, Md., but to a limited extent in Anne Arundel County, Md. It is undoubtedly a type of limited geographical extent and of restricted agricultural importance.

The surface soil of the Sassafras loamy sand to a depth of 6 or 8 inches is a dull-brown loamy sand. The medium to coarse grades of sand form a considerable part of the whole mass and give a coarse gritty character to the material. A small amount of white quartz gravel is also found in the surface soil. There is present a sufficient amount of finer grained material to cause a moist sample of the soil to cohere slightly, but when dry the surface soil is loose and uncompacted, although not quite so incoherent as the Sassafras sand.

The upper part of the subsoil possesses about the same texture and structure as the soil, but is lighter in color, being a pale yellow. At a depth of 15 inches there is a perceptible increase in the amount of fine material and the deeper subsoil gradually becomes a moderately heavy sandy loam. It is coherent when moist, but crumbles into granular aggregates when dry.

The Sassafras loamy sand is an intermediate gradation between the Sassafras sand and the Sassafras sandy loam. For the general farm crops it ranks below the latter and above the former.

The most extensive areas of the Sassafras loamy sand are level to gently undulating in surface topography and sufficiently elevated to be well drained to droughty. There are some areas where the deeper subsoil is rather poorly drained, but these are of limited extent.

A considerable part of the Sassafras loamy sand has been cleared and occupied for the production of the general farm crops. More recently areas located near to canning factories or to shipping facilities have been used to some extent for the growing of tomatoes for canning, of sweet potatoes, and of melons and cantaloupes.

Among the grains, corn is most extensively grown. The yields obtained are low under ordinary systems of management. Wheat also gives low yields upon this soil. Some crab grass is cut for hay. Crimson clover has been tried upon this soil and gives fair yields of hay, especially when a light application of lime is made with the seeding. Cowpeas are also grown to some extent, chiefly as a hay crop. It has been found that the other general farm crops produce larger yields following a crop of crimson clover, and the practice of using this legume as a winter-cover crop and for the purpose of green manuring should be extended.

Where tomatoes are grown for canning moderate yields are secured. Crimson clover is frequently grown as a green manure in connection with this crop, giving markedly increased yields.

Buckwheat and rye are grown to a very limited extent.

The Sassafras loamy sand may be characterized as a rather low-grade general farming soil which is much better suited to the growing of special crops where a market for such crops, especially tomatoes, sweet potatoes, and melons, exists.

This type is normally deficient in organic matter, and the use of stable and green manures is to be recommended.

SASSAFRAS FINE SAND.

The Sassafras fine sand has been mapped in the Trenton area, in New Jersey and Pennsylvania, and in Anne Arundel and Prince Georges Counties, Md., to a total extent of 78,302 acres.[1] In the Trenton area this soil type is found on both sides of the Delaware River from the vicinity of Trenton southward. In Maryland no areas of the Sassafras fine sand have been encountered, except along the upper course of the Patuxent River. It is probable that the type is not of widespread occurrence outside of the localities where it has already been mapped.

[1] Considerable areas of this soil were included with the Sassafras sand in the Salem area, New Jersey.

The soil of the Sassafras fine sand, to an average depth of 8 or 10 inches, is a brown or reddish-yellow fine sand. It is friable and powdery when dry but slightly adhesive when moist. The subsoil is a lighter colored, yellow or pale orange fine sand which is usually rather incoherent to a depth of 2 feet or more but may be somewhat cohesive below that depth.

The surface configuration of the Sassafras fine sand varies considerably in the different localities where it is found. Along the Delaware River it occupies level-topped to undulating terraces at elevations varying from 10 feet to 80 feet above tide level. In the Maryland counties it occurs as level terraces at various elevations above the Patuxent River and also as rolling to rather hilly country at some distance back from the river. In all of these positions there are numerous steep slopes within the limits of the type. The terrace occurrences present considerable areas of level arable land, while the rolling areas frequently show not more than half of the surface sufficiently level for tillage purposes. In all positions the natural drainage of the type is good and sometimes excessive. On the steeper slopes there is constant danger from excessive erosion and this limits the uses to which the land may be put as well as the total area which may be used for tillage. The steeper slopes are usually forested with mixed hardwood growths.

In New Jersey and Pennsylvania the areas of the Sassafras fine sand exist near to large city markets and there has been a considerable development of this type for the purposes of market gardening and trucking. Very little use is made of it for the production of general farm crops. In Maryland, however, it is not favorably located with respect to market or to transportation, and the crops grown are those of the general agriculture of the community. It is probable that nearly three-fourths of the entire area of the Sassafras fine sand has been cleared and occupied for some form of agricultural production.

The class of crops grown upon the Sassafras fine sand depends chiefly upon the market facilities. Thus, upon the larger areas of the type along the Patuxent River, corn, wheat, grass, and the Maryland pipe-smoking tobacco constitute the chief crops. Corn gives moderate to low yields, ranging from 15 to 30 bushels per acre. Wheat gives yields which range from 10 to 15 bushels. Hay is not generally grown, but where produced yields of less than 1 ton per acre are common. The quality of the Maryland pipe-smoking tobacco produced upon this soil is fair to good, but the yields are frequently low. In fact, the water-holding capacity of the type under normal conditions is not great enough to mature large yields of the staple crops. Cowpeas and crimson clover have only been grown to a small extent upon the Sassafras fine sand. The general introduc-

tion of these crops both for forage and green manuring purposes should be encouraged.

The Sassafras fine sand can not compete with the Sassafras sand in maturing truck crops at a very early date, but the crops grown are usually satisfactory with regard to yields. For the production of early tomatoes, of sweet potatoes, and of garden peas and string beans the Sassafras fine sand is well suited. It is used for the growing of these and other market garden crops in southwestern New Jersey. It is also used for the growing of cantaloupes and is well suited to this crop.

In general, the Sassafras fine sand is somewhat too porous and well drained to be classed as a successful general farming soil. Areas suitably situated with regard to market are used for vegetable crops and canteloupes.

In all cases the sandy character of the soil renders the use of organic manures and green manuring crops advisable.

SASSAFRAS GRAVELLY LOAM.

The Sassafras gravelly loam has been mapped to the extent of 164,678 acres, chiefly upon western Long Island and in southwestern New Jersey. Only small areas of the type have been found elsewhere, chiefly in the Maryland counties on both sides of the upper reaches of Chesapeake Bay.

The soil of the Sassafras gravelly loam to a depth of 8 to 10 inches is a brown or reddish-yellow sandy loam containing from 20 to 40 per cent of small, white, quartz gravel, intimately mixed through the mass of finer grained material. This is usually underlain by a yellow or reddish-yellow silty loam which also contains considerable gravel. The whole mass rests upon beds of fine or medium gravel at depths ranging from 2 to 3 feet.

The surface features of the Sassafras gravelly loam are somewhat variable in the different areas of its occurrence. The extensive area mapped on western Long Island constitutes a gently sloping plain with a maximum elevation of 200 to 240 feet above tide level where it abuts against the latest glacial moraine ridge along the northern shore of the island. Thence it slopes gently seaward to the south shore, being interrupted by the ridges and hills of an earlier moraine in the central part of Long Island.

The surface is little broken by stream channels although a few dry gullies carry off excess water in times of heavy precipitation or of melting snow. The natural slope of the land and the presence of the underlying, porous beds of gravel give the type complete drainage throughout its occurrence upon Long Island.

In southwestern New Jersey some areas of the Sassafras gravelly loam occur chiefly on upland ridges and sloping plains, where erosion has partially removed the original covering of silt loam. It also occurs in narrow belts as a gravelly outcrop along stream slopes. In both positions it is rather excessively drained because of its coarse texture and because of the presence of underlying beds of sand and gravel. Upon the more level areas, where erosion has not been so severe, there still remains a sufficient amount of silty fine earth to render the type capable of fairly successful agricultural occupation.

The other areas of the Sassafras gravelly loam are chiefly local tracts, where an unusually high content of gravel is found in material resembling either Sassafras sandy loam or the loam.

Considerable portions of the type are too sloping and too completely drained to constitute good farm land. The more level areas, such as that upon Long Island, have been utilized to quite an extent for the production of special crops.

In general the staple farm crops are not extensively grown upon the Sassafras gravelly loam. In the Maryland areas, however, corn gives yields of 20 to 35 bushels per acre upon portions of the type which are not too sloping and gravelly to retain sufficient moisture for maturing the crop. Wheat is grown in the regular crop rotation, giving yields of 12 to 15 bushels per acre. Clover is usually seeded with the wheat, returning yields of 1 ton or more per acre. Locally cowpeas are grown to a limited extent. Some tomatoes are also grown in localities near canning factories.

Owing to its proximity to great city markets and to the fact that the soil is well drained and warm, the market garden and truck crops are grown upon it in large acreage on western Long Island.

Early Irish potatoes are extensively grown and the yields obtained with liberal use of manure and fertilizer range from 100 to 200 bushels per acre. The crop reaches the market late in August and is chiefly marketed as fast as it matures. Cabbage for the summer and early fall market is also grown. Sweet corn for direct sale constitutes another important crop, while tomatoes are raised to a small extent.

In New Jersey few general farms crops are grown upon the Sassafras gravelly loam. In some localities plantings of peaches, plums, cherries, and pears have been made. They have been fairly successful. The growing of market garden and truck crops has also been undertaken during the last 10 years and small areas of the type are thus utilized.

For the production of either the vegetables or fruit crops it is essential to select only those portions of the Sassafras gravelly loam which contain a considerable amount of silt and clay in both the

surface soil and subsoil and to avoid the areas of the type underlain at a shallow depth by thick or compacted beds of gravel. Where the surface layer of loamy and gravelly soil and subsoil amounts to 3 feet or more the type possesses a considerable agricultural value. Elsewhere it is too completely drained and the gravel bed interferes too seriously with root development.

In general the Sassafras gravelly loam is not well suited to the staple farm crops. Certain special fruit and vegetable crops are grown where the loam content is greatest and where the local demand furnishes a good market for early vegetables or fruits.

In all areas the Sassafras gravelly loam is benefited by the addition of organic manures.

SASSAFRAS SANDY LOAM.

The Sassafras sandy loam has been mapped to the extent of 332,410 acres in the soil surveys which have been made in southern New Jersey, Delaware, eastern and southern Maryland, and in the vicinity of Norfolk, Va. It is one of the most extensively developed and agriculturally important types in the Sassafras series. It is probable that additional soil surveys in these general localities will show the existence of other areas of this soil.

The soil of the Sassafras sandy loam to an average depth exceeding 1 foot is a brown, granular sandy loam. It is characterized by a fairly even distribution of the coarse, medium, and fine grades of sand with a relatively large proportion of silt, which gives a decided coherency to the soil mass.

The subsoil is a reddish-yellow or brown sandy loam decidedly heavier and more coherent than the surface soil. This extends to a depth of 2 or 3 feet, where it is normally underlain by coarse sand or fine gravel. There are areas of limited extent where the more pervious deeper layer is not found and some portions of the type, particularly in the New Jersey occurrences, are underlain by a stiff clay. These are not strictly typical of the Sassafras sandy loam.

Upon portions of the type which slope down to stream courses a small amount of quartz gravel and occasionally a few small stones are found. Such areas are of decidedly limited extent, and the type as a whole is a remarkably uniform medium sandy loam.

All of the more extensive areas of the Sassafras sandy loam possess a nearly level or very gently undulating surface topography. They occur principally within the low-lying coastal terraces which border the Delaware River and Bay and in the broad, gently sloping plain which lies between Delaware Bay and Chesapeake Bay. The absolute elevation of the surface of the type ranges from 5 to 10 feet above tide level near the coast line, to altitudes of 70 or 80 feet above tide upon the more elevated inland ridges. West and south of Chesa-

peake Bay the areas are of small extent and are found upon low coastal or river terraces.

In all the areas of its occurrence the Sassafras sandy loam is well drained in its natural condition and only a very small proportion of the type requires artificial drainage to render it suitable for agriculture.

The generally level or slightly undulating surface renders the use of power machinery possible over practically the entire extent of this soil. It is thus admirably suited by its natural characteristics for the development of many classes of farming.

It is probable that more than 80 per cent of the total area of the Sassafras sandy loam has been cleared and utilized for some form of agriculture. The class of farming developed depends to a considerable degree upon the location of the particular area of the type with respect to markets and transportation, since the soil itself is fairly well suited to the conduct of a high class of general farming or to a more intensive form of special crop production. For both of these classes of farming it is held in high esteem and is consequently very generally under cultivation. Only local areas of considerable slope are left in natural forest.

Among the staple farm crops, corn is more extensively grown upon the Sassafras sandy loam than any other. The yields of corn reported from this type range from 35 to 40 bushels an acre under normal circumstances, while yields of 65 bushels or more have been attained under especially favorable conditions of season and where extra care was used in the preparation of the land and in the cultivation of the crop. In the latitudes in which the Sassafras sandy loam occurs the dent varieties of corn are almost exclusively grown for the field crop.

Wheat is most extensively grown among the small grains and gives yields which range from 12 to 18 bushels per acre under normal conditions, but with authentic yields in excess of 30 bushels per acre. The Sassafras sandy loam is rather porous and sandy to be classed as a first-rate wheat soil, but the yields obtained show that the crop may be used successfully in the general farm rotation.

Oats and rye are both grown to a small extent upon this soil. The yields are not sufficiently high to warrant increasing the acreage.

Cowpeas are grown to some extent on the Sassafras sandy loam in Delaware and the Eastern Shore of Maryland. The crop is not common, however.

Crimson clover, or "scarlet" clover, as it is locally termed, has been grown upon the Sassafras sandy loam and associated soils for nearly 30 years. Excellent fields in eastern Maryland are shown in Plate III, figures 1 and 2. Within the past 10 years the area annually seeded to this crop has been greatly increased, and the value

of crimson clover both as a forage crop and as a soil renovator has led to its quite general introduction into the crop rotation of the Maryland-Delaware Peninsula. The crimson clover is sown in the growing corn at the last working or at a special working in early August. It is also sown in the tomato fields. After the corn is harvested the clover makes a good fall growth and then lies dormant during the winter. In early spring it grows rapidly and is ready for cutting for hay by the middle of May. This allows the cutting of a hay crop, ranging from 1½ tons to as high as 3 tons per acre, and the plowing down of the stubble in time for the planting of another crop of corn, tomatoes, or cowpeas.

Some farmers obtain a crop of corn, follow with a seeding to wheat, and after the wheat is harvested either plow or disk harrow the wheat stubble, seeding to crimson clover. The next spring the clover is either cut for hay or it is grazed off by hogs, sheep, or cattle, in which case a considerable residue of the plant is available to be plowed under as a green manure for a succeeding corn crop.

The favorable effect of crimson clover upon the Sassafras sandy loam in securing increased yields of the other staple and special crops has led to a gradual extension of its production, especially in central Delaware and in adjacent parts of Maryland. The yields of corn grown upon a crimson clover sod are materially greater than where the crop is grown on land upon which no winter cover crop has been planted.

It has been found desirable to apply lime to a field where crimson clover is first to be seeded. This may be done at the rate of 1,000 to 2,000 pounds per acre of quicklime, or at the rate of 1 or 2 tons per acre of ground limestone.

Medium red clover is quite commonly seeded in the spring on wheat upon the Sassafras sandy loam. The clover usually gives a good hay crop, ranging from 1 to 2 tons per acre. To a limited extent timothy and clover are used for seeding for mowing lands and a fair yield of mixed hay results. The success attained with crimson clover and with red clover, however, restricts the area seeded to mixed grasses.

A very small acreage of buckwheat is grown upon the Sassafras sandy loam, chiefly as a catch crop or as a winter cover crop.

In the southern Maryland counties the Maryland pipe-smoking tobacco is grown to some extent upon the Sassafras sandy loam. The yields range from about 1,000 pounds to as much as 1,500 pounds per acre. The quality of the tobacco is usually good.

While the general farm crops occupy by far the larger acreage upon the Sassafras sandy loam, special vegetable and fruit crops are also grown to a considerable extent, especially in central Delaware and the eastern counties of Maryland.

Early Irish potatoes are produced to fair advantage upon this soil. The yields are extremely variable, ranging from 75 to 250 bushels per acre. The general average is about 100 bushels. The potatoes from this type in Delaware reach the northern markets during July and succeed the shipments from points farther south. Wherever the type occurs, from the vicinity of Norfolk, Va., to the Delaware Bay region, it is recognized as a soil well suited to the growing of early Irish potatoes. The extension of the production of this crop has been rather rapid during the last 10 years.

Sweet potatoes are also grown in considerable acreage upon the Sassafras sandy loam. The yields are fair to good and the quality of the potatoes is usually excellent.

Tomatoes are grown both for shipment to city market and for supplying local canning factories. Yields range from 4 to 6 tons or more per acre, and the crop has generally been found to be profitable.

Sweet corn is grown both for direct sale and for canning.

Peas, cucumbers, cantaloupes, watermelons, and asparagus are all grown successfully, but in small acreages, upon the Sassafras sandy loam.

In central Delaware the Sassafras sandy loam has been developed as the most important fruit soil of the region. Pears occupy the largest acreage, and the Kieffer is the principal variety. It is used for canning chiefly.

Peaches were extensively grown at one time, but the acreage has greatly decreased during recent years because of the trouble experienced from various diseases, principally yellows and little peach. The Elberta peach is the standard variety in the present orchards.

Many varieties of early summer and fall apples are successfully produced upon the Sassafras sandy loam. Among the early varieties may be mentioned Yellow Transparent and Early Ripe. Williams is grown for the summer market, while Stayman Winesap, Nero, Paragon, Winesap, York Imperial, and Rome are planted to supply the fall and winter markets. Very considerable plantings of apple orchards have been made upon the Sassafras sandy loam in central Delaware during the last 20 years. It has been found that this soil brings the trees to bearing age in 5 to 12 years. A young apple orchard and a planting of blackberries on the Sassafras sandy loam are shown in Plate IV, figure 1.

Grapes are being planted to quite an extent in the vicinity of Dover, Del., largely upon the Sassafras sandy loam. Moores Early and Concord are the varieties chiefly grown. Practically all of the fruit is shipped for table use. A vineyard in the vicinity of Dover, Del., is shown in Plate IV, figure 2.

Among small fruits the strawberry occupies the largest acreage upon the Sassafras sandy loam. The early variety is chiefly the

Superior, while the Klondyke is grown as a midseason berry. The later varieties are not grown with as great success upon the Sassafras sandy loam as upon the more mucky and darker colored soils of the Portsmouth series.

Dewberries and blackberries occupy a minor acreage upon the Sassafras sandy loam.

SASSAFRAS FINE SANDY LOAM.

The Sasasfras fine sandy loam has been mapped to a total extent of 101,676 acres in the different soil surveys which have been made in the northern portion of the Coastal Plain. The largest areas of the type are found in the Maryland counties which border the western shore of Chesapeake Bay. Small areas are also found along the lower courses of the Delaware River and on the eastern shore of Maryland.

The surface soil of the Sassafras fine sandy loam, to an average depth ranging from 9 inches to 1 foot, is a brown to yellowish-brown fine sandy loam. In some areas a small amount of quartz gravel is found in the surface soil, particularly upon sloping areas. There is also an appreciable amount of silt in the lower portions of the surface soil in such positions. In general the soil is soft and friable, but somewhat coherent when moist.

The subsoil in all cases is a heavier and more compact yellow or reddish-yellow sandy loam, which normally extends to a depth exceeding 3 feet. In many areas the subsoil grades downward into a more sandy layer which underlies it at depths varying from 3 to 5 feet. In some cases, especially where the surface is flat and the total depth of subsoil is considerable, the deeper subsoil may be compact and rather poorly drained. In such cases it is sometimes mottled yellow and gray.

The surface configuration of the Sassafras fine sandy loam varies considerably in the different areas of its occurrence. Along the Delaware River and at the lower elevations on the Eastern Shore of Maryland and bordering Chesapeake Bay the type occupies low-lying, nearly level topped terraces, which extend from the vicinity of tidewater to elevations of 25 or 30 feet. These terraces are generally fairly well drained, although small depressions or level areas somewhat remote from local drainage ways may be semiswampy in their natural condition. In Anne Arundel County, Md., where the greatest area of this type has been encountered, the surface is rolling to sloping in character and lies at altitudes of 40 to 150 feet above tide level, and drainage has become well established over practically all of the type. Probably three-fourths of the entire extent of the Sassafras fine sandy loam is well drained.

FIG. 1.—CRIMSON CLOVER ON SASSAFRAS SANDY LOAM IN EASTERN MARYLAND, READY FOR CUTTING.

FIG. 2.—HARVESTING A HEAVY CROP OF CRIMSON CLOVER HAY BEFORE PLANTING CORN ON THE SAME LAND, EASTERN MARYLAND.

FIG. 1.—YOUNG APPLE ORCHARD AND PLANTING OF BLACKBERRIES ON SASSAFRAS SANDY LOAM IN CENTRAL DELAWARE.

FIG. 2.—VINEYARD ON SASSAFRAS SANDY LOAM IN CENTRAL DELAWARE.

Nearly all the well-drained areas of the type have been cleared and placed under cultivation, and only the more level and poorly-drained areas remain in forest.

Corn is more extensively grown than any other grain crop upon this soil, and the yields obtained range from 20 to 40 bushels per acre, probably averaging about 30 bushels for the entire type. The dent varieties are almost exclusively grown.

Wheat also occupies a large acreage upon the Sassafras fine sandy loam. The yields of this grain range from 12 to 15 bushels per acre to as high as 20 bushels. The general average for the type may be stated at about 15 bushels.

The Sassafras fine sandy loam is generally recognized as being well suited to the production of the Maryland type of pipe-smoking tobacco, and this crop is quite generally grown as the cash crop upon this soil in all of the southern Maryland counties. Its production is confined to these counties and none is grown east of Chesapeake Bay. The yields of tobacco range from 1,000 to about 1,200 pounds per acre, and the quality is generally good.

Oats and rye are only grown to a limited extent.

A seeding to mixed timothy and red clover is frequently made with the wheat crop and fair yields of hay, ranging from 1 to 1½ tons per acre, are obtained. In some localities clover is seeded alone and gives yields of 1½ tons per acre or more.

Where areas of the Sassafras fine sandy loam are located in proximity to canning factories it has been found profitable to use the land for the production of tomatoes. Fair yields, ranging from 4 to 7 tons per acre are obtained, and the production of the crop is being extended in such localities.

Truck crops are grown to a small extent upon this soil, chiefly because the greater proportion of the type is not well located with respect to transportation. It has been found that early Irish potatoes, sweet potatoes, cantaloupes, and cucumbers may be successfully grown upon it where market facilities are available.

In the majority of the areas of its occurrence the Sassafras fine sandy loam has been used to some extent for the growing of peaches, pears, apples, and plums. Where the local air and water drainage are good the tree fruits may be grown with fair success.

Whether the Sassafras fine sandy loam is to be used for the production of general or special crop it has been found that it requires the use of considerable amounts of organic manure to give large yields. Generally, not much live stock is maintained upon the type so that the supply of stable manure available is small. The practice of growing green manuring crops is not general upon this soil. It has been shown that both cowpeas and crimson clover make good

crops upon the type and the production of both for hay, and as green manuring crops, should become more general.

The Sassafras fine sandy loam may be characterized as a fairly good general farming soil, capable of considerable improvement through the introduction of leguminous green manuring and forage crops into the normal rotation of corn and wheat. It is also a fairly good soil for growing some of the vegetable crops wherever market facilities are available. It is moderately good soil, in the localities where it occurs, for the production of some of the tree fruits, although not to be recommended for extensive commercial plantings.

SASSAFRAS LOAM.

A total area of 128,356 acres of the Sassafras loam has been encountered in the soil survey work. By far the greater part of the type is found in the eastern counties of Maryland, between Delaware Bay and Chesapeake Bay. Small areas are also found on Western Long Island and in southern Maryland.[1]

The surface soil of the Sassafras loam to an average depth of 8 inches or more is a mellow brown or yellowish-brown loam. It is soft and silty in character. It grades downward into a stiffer and more compact yellow loam subsoil which becomes distinctly reddish in tinge at depths of 24 to 32 inches. The subsoil is usually underlain by fine gravel or coarse sand at depths ranging from 2 to 3½ feet.

The character of the soil and subsoil is such that a considerable amount of moisture is easily retained for crop production while effective drainage is promoted over the greater proportion of the type by the presence of the coarser material lying at greater depth.

Under ordinary conditions of cultivation the surface soil is easily worked and friable. Where the organic matter content of the surface soil has become reduced and especially where the land has been grazed when the soil was too wet there is a tendency toward compacted surface soil and toward breaking into clods and lumps when the land is plowed.

The Sassafras loam is chiefly developed upon the low, rolling uplands of the eastern counties of Maryland and upon the nearly level surfaces of the interstream ridges in the counties west of Chesapeake Bay. The small area on western Long Island lies at low elevations and is gently sloping to nearly level. In general there are few steep slopes within the area of this soil type. The recognized value of the Sassafras loam as an excellent general farm-

[1] It is probable that considerable areas of the Sassafras loam have been included in the areas of the Sassafras silt loam in the surveys of Cecil, Harford, and Kent Counties, Md. These can not be separated at the present time.

ing soil has led to its almost complete occupation for the production of various staple crops.

Throughout the entire extent of its development the Sassafras loam is naturally well drained, although minor areas which occupy depressed positions or very flat surfaces remote from stream drainage may be somewhat poorly drained and in need of tiling for the best results in crop production. Usually the somewhat elevated position of the type, its occurrence in regions of well-established stream drainage, and particularly the general existence of the more porous underlying sandy layer give rise to perfect natural drainage.

The Sassafras loam is essentially a soil well fitted for the growing of the staple field crops which constitute the basis for general farming in the areas where it occurs.

Wheat is the crop most extensively grown upon the Sassafras loam. It is probable that it occupies nearly or quite one-half of the total area of the type which is annually planted to crops. This arises from the fact that a 5-year rotation is in common use which consists of corn, followed by wheat with seeding to clover. The clover is cut one year and then plowed for another seeding of wheat. Clover is again sown on the wheat, cut for one year and the rotation returns to corn. While this rotation is much practiced, the 3-year rotation of corn, wheat, and clover is also common. The acreage statistics in counties where the Sassafras loam is an important soil type bear out the indication that wheat is the most extensively grown grain crop.

While there is considerable variation in the average crops of wheat secured it may be said that the yields range from 15 to 30 bushels per acre with a general average of about 20 bushels. The quality of the wheat grown upon this soil is usually better than the average and the general opinion is held that wheat is one of the crops best suited to the Sassafras loam. It is a notable fact that the counties in which this soil and the closely related Sassafras silt loam are most extensively developed have increased the acreage and production of wheat during the past 25 years.

The Sassafras loam may safely be ranked as one of the types best suited to wheat in the northern Coastal Plain region.

Corn is the second crop in acreage and importance upon the Sassafras loam. It is probably nearly equaled in extent of acreage by the various grass crops, although the failure to seed to grass with a portion of the wheat crop annually reduces the area in grasses.

The yields of corn reported from the Sassafras loam range from 40 to 75 bushels per acre. It is probable that the general average for the type is in the vicinity of 45 bushels per acre.

It is stated in the Soil Survey of the Easton Area, Md., that—

Where the soil is kept in a good state of productiveness, as under a 5-year rotation of corn, wheat, grass, wheat, and grass, applying barnyard manure

and 40 bushels of lime to the broken grass sod preceding corn and about 300 pounds of good commercial fertilizer to wheat, average yields of 60 bushels of corn, 20 bushels of wheat after corn, and 28 bushels after grass, and 1½ tons of hay per acre are readily secured.

While these returns are distinctly above the ordinary yields of the type they represent its capabilities as a grass and grain-producing soil under the unusually good methods of management given.

A considerable acreage of hay is annually grown upon the Sassafras loam. Where a regular crop rotation is used and the wheat crop is adequately fertilized the yields of clover or of mixed clover and timothy range from 1 to 2½ tons per acre.

Oats are grown to a very limited extent upon the Sassafras loam. Rye is an uncommon crop. Cowpeas have been successfully grown in some cases, and the type seems well suited to the production of this crop. Crimson or scarlet clover is coming to be grown upon the Sassafras loam, but the crop is not nearly so common as on the more sandy members of the series. The yields obtained are good, ranging from 1½ to 3 tons per acre.

It has been found by progressive farmers that the use of lime on the Sassafras loam is a profitable practice. The lime is usually applied in the form of lump, quick lime, which is slaked in the field. Applications vary from 20 to 40 bushels per acre. The chief benefit of liming is held to be in the increased crop of clover secured after its application, which later results in improved grain crops grown upon the clover sod. It is probable that finely ground limestone or oyster shells applied at the rate of about 2 tons per acre would be equally beneficial.

Tomatoes are grown to quite an extent on the Sassafras loam, and the yields range from 4 tons per acre upward. The crop is chiefly grown for near-by canning factories.

Market garden and trucking crops are grown upon some areas of the Sassafras loam where markets are available. Beans, peas, cabbage, and cantaloupes are the principal crops grown.

The Kieffer pear is most extensively grown among orchard fruits, although Winesap, York Imperial, and other varieties of apples are reasonably successful upon this soil. Large nurseries are located upon one part of the type and many varieties of fruit trees are grown and distributed.

Peaches were at one time extensively grown, but yellows and other diseases have led to the practical abandonment of the crop upon nearly all of the Sassafras loam.

Among the small fruits, strawberries, dewberries, and blackberries are grown in some localities to a small extent.

The Sassafras loam is characteristically a general farming soil, well suited to the growing of corn, wheat, and grass. The knowl-

edge of the adaptation of this soil to these crops is general and the agriculture of the type is chiefly based upon the production of these three crops. Only locally is the Sassafras loam used for the growing of tomatoes and other special crops. The vegetables are chiefly grown for home use or to a small extent for special markets.

Considering the excellent yields of corn and grass attained from the Sassafras loam there is a rather small amount of any live stock aside from work animals maintained upon the type. Some dairy cows are kept as an adjunct to grass and grain farming and a few steers are fattened, but the total number of neat cattle kept upon the type is small. Nearly every farm principally consisting of this soil maintains a few hogs, while some sheep are seen upon it. Yet the live-stock industry is subordinate over the greater part of the Sassafras loam.

Few Coastal Plain soils equal the Sassafras loam for the uses which have been indicated.

SASSAFRAS SILT LOAM.

The areas of the Sassafras silt loam which have been encountered in the soil survey are confined entirely to the Coastal Plain portions of New Jersey, Pennsylvania, Delaware, and Maryland. A total area of 518,142 acres of this type has been included in 12 different soil surveys in these 4 States.[1] It is probable that the soil type does not occur farther north than New Brunswick, N. J., nor farther south than Norfolk, Va.

The surface soil of the Sassafras silt loam, to an average depth of 9 or 10 inches, is a soft, friable, brown silt loam, occasionally containing small amounts of fine gravel. This is underlain to a depth of 36 inches in nearly all cases, and frequently to a depth of 7 or 8 feet, by a yellow or reddish-yellow heavy silt loam, which is generally sufficiently heavy to be called a clay in the localities where it occurs. At a depth varying from 3 feet to 8 or 10 feet this subsoil is frequently underlain by beds of gravel or gravel and sand, which separate the mass of soil and subsoil from underlying formations. This feature is shown in Plate V, figure 1. In the southern portion of the Maryland-Delaware Peninsula, however, this gravel bed is frequently lacking, and the subsoil rests not infrequently on beds of sand. While the subsoil is rather stiff and heavy, it is still sufficiently granulated and friable to give moderate underdrainage, and it is only in case of depressions occurring within the type that drainage is likely to be deficient.

Throughout the region in which it occurs the Sassafras silt loam occupies low, undulating plains or nearly level terraces, which slope

[1] It is probable that portions of the type as mapped in Cecil, Harford, and Kent Counties, Md., should be included with the Sassafras loam.

from the inland regions gently to a rather steep frontal escarpment, where the type ordinarily terminates, and is replaced at lower levels by other soils. In southern New Jersey the soil type is found at an altitude of 25 to 50 feet on the low terraces which border the eastern shore of the Delaware River and Delaware Bay, and it rises gently inland to a higher level at about 140 feet altitude. Some portions of the type between the low and the higher terrace are rolling to sloping in their surface features. In the Maryland-Delaware Peninsula the highest altitudes of the type are found in the form of narrow terraces where the Coastal Plain section borders on the Piedmont. Some of these higher terraces rise to an altitude of 200 feet or more. In general the highest altitudes of the Sassafras silt loam within the Coastal Plain proper are found at about 100 to 110 feet above tide in the vicinity of Chesapeake Bay, and the surface slopes gently eastward toward Delaware Bay through Maryland and central Delaware, reaching its lowest level of about 10 feet above tidewater in the east-central part of the State of Delaware. In southern Maryland the Sassafras silt loam exists along the west shore of Chesapeake Bay and along the main tidewater embayments tributary to the bay in the form of distinct terraces, having an altitude of 60 to 100 feet above tidewater. Some of these terraces extend a considerable distance inland along the principal streams, and their surface rises gently with the slope of the stream bed to altitudes of over 100 feet. In all regions where it occurs the surface is so level that power machinery may be used upon all parts of the type when it is properly cleared of its natural hardwood growth. The altitude above the local water level renders the natural drainage effective over the greater proportion of the type. Slight hollows and level tracts remote from the drainage courses constitute the only exception to this general rule.

Although the Sassafras silt loam is remarkably uniform in its inherent characteristics from its most northern extension to its southern limits, there are noticeable variations in the yields of the general farm crops which are produced upon the type. In the more northern regions, where this soil is highly esteemed for general farming, it has been the subject of the most careful tillage and treatment. As a result the yields of all the farm crops are high, and the soil is rarely sold at a price lower than $75 to $100 an acre. Farther south, where a different and less effective system of farming has been in use, the yields are less, the price of the land is not more than one-third as great, and the surface soil is more yellow and lacks sufficient organic matter. It is also more likely to be compacted and clodded when cultivated in a moist condition. These differences in its condition indicate the chief limitations upon the producing capacity of the Sassafras silt loam. Where a careful and systematic

crop rotation is practiced, where stable manure and other organic manures are used, and particularly where moderate amounts of lime are applied in connection with the seeding down of the grasses and clover, maximum yields are always obtained, and the soil is found to be in its best condition. On the contrary, where organic manures are not used, where liming is never practiced, and where hoed crops are cultivated year after year upon the same area, the soil is much less productive and much less esteemed for the production of crops. The introduction of better methods in the regions last referred to will slowly increase the producing capacity of this soil and render it as fertile and as valuable as in the locations where it has received better treatment in the past. In all cases the natural capacity of the soil is above the average for each region where it occurs.

The necessary steps for the improvement of crop yields upon this type have already been indicated in the discussion of the limitations of such yields. One of the paramount necessities is the application of all stable manure which is available, and in case this supply is not sufficient to meet the needs some leguminous crop like crimson clover or the medium red clover should be produced for the sole purpose of being plowed under to increase the humus content, preferably with an application of 2,000 pounds of lime per acre. In certain localities difficulty has been encountered in securing a good stand of clover upon this soil type. Liming will largely overcome this difficulty, and better results can be obtained by seeding the clover without a nurse crop.

There are small local areas within the general area of the type where additional artificial drainage would prove beneficial. These usually consist of small saucer-shaped depressions or of flat interstream areas where the headwater drainage of the streams is only partially established.

Practically every available acre of the Sassafras silt loam has been brought under cultivation in the various regions where it occurs. It is one of the most highly prized general farming soils of the North Atlantic Coastal Plain section, and the original hardwood timber was cleared from its surface from 100 to 200 years ago. The soil type was early sought for the production of corn, wheat, and grass, and certain special crops have been produced upon it with success as transportation facilities and market demands increased. While there is considerable variation in the yields produced, owing to more or less efficient management, it is naturally an excellent soil for general farming.

It is apparent from the textural characteristics of the Sassafras silt loam, from its level to gently undulating surface topography, and from the classes of crops best suited for production upon this soil that the equipment required for its most economical tillage will

differ very materially from the equipment to be used upon the more sandy Coastal Plain soils. The Sassafras silt loam should be plowed to a depth of 8 or 9 inches, and if the natural soil is not so deep as this the depth of plowing should be gradually increased from year to year until the desired maximum is reached.

Economy in the conduct of tillage operations demands that at least two-horse teams where each animal will weigh from 1,300 to 1,500 pounds should be used, and the most economical working of land of this class would justify the four-horse hitch, which is used to special advantage upon the heavy general farming soils, such as the limestone soils of Maryland and Pennsylvania and the prairie soils of the Central States.

For the same reasons the lightweight turning plow used upon the more sandy soils of the Coastal Plain is totally inadequate for the proper tillage of the Sassafras silt loam. In its place there should be used either the one or two gang sulky plow or the two or three blade disk plow. These implements, drawn by adequate horsepower, are capable of turning and thoroughly pulverizing the surface soil to the required depth of 8 or 9 inches. Less powerful equipment, either of team or tools, is not competent to bring out the best qualities and the full efficiency of the soil. The use of adequate tillage implements is shown in Plate V, figure 2.

Both the soil and subsoil require frequent stirring, and it is desired to use such implements as the disk harrow, the spring-tooth harrow, or the spike-tooth harrow to secure this preparation of the land. Wherever possible, horsepower machinery should also be used for the planting and intertillage of crops.

In the same way that heavier teams and tools are required for the proper tillage of the Sassafras silt loam, so also are more expensive and commodious farm buildings requisite. These exist in New Jersey and on the Maryland-Delaware Peninsula, where the soil type is most profitably tilled. The storage of grain, hay, and straw and the proper housing of tools and work stock, even in the absence of the dairy industry or of cattle breeding, require the more elaborate equipment of buildings and barns. Typical farm buildings are shown in Plate VI, figure 1.

Thus the nature of the soil and its characteristic properties determine the character of the best farm equipment in the form of work stock, machinery, and buildings.

The Sassafras silt loam is probably the best general farming soil to be found in the northern part of the Coastal Plain regions. Its level surface, its soft, friable surface soil when properly handled, the considerable depth of both surface soil and subsoil, and the adequate drainage features of the type all tend to render it suitable for

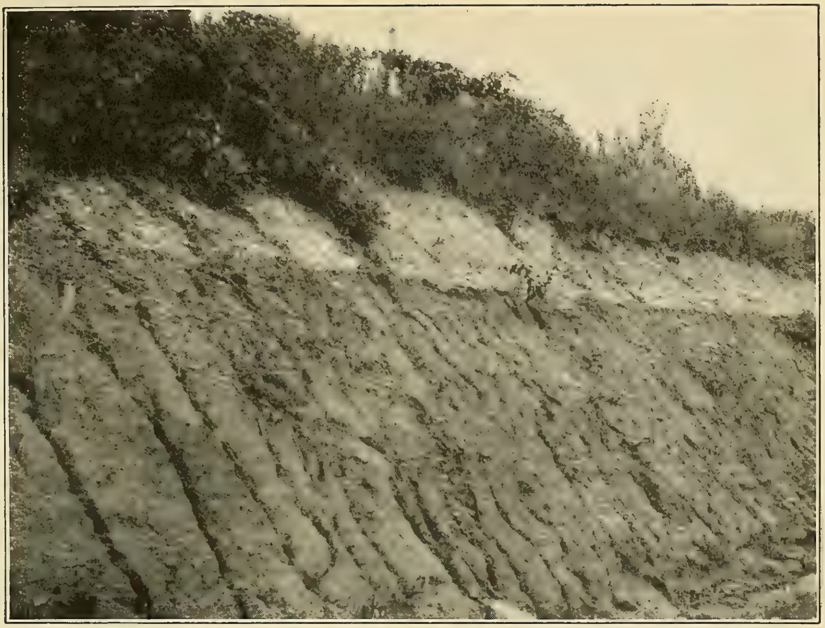


FIG. 1.—GRAVEL BED WHICH IS GENERALLY FOUND UNDERLYING THE SOILS OF THE SASSAFRAS SERIES, KENT COUNTY, MD.

FIG. 2.—DISK HARROW USED IN PREPARING THE SEED BED ON THE SASSAFRAS LOAM AND SILT LOAM.

FIG. 1.—TYPICAL GROUP OF FARM BUILDINGS ON THE SASSAFRAS SILT LOAM IN EASTERN MARYLAND.

FIG. 2.—CORN ON SASSAFRAS SILT LOAM IN KENT COUNTY, MD.

the production of the principal farm crops of the latitude in which it occurs.

The Sassafras silt loam is extensively used for the production of corn. The dent varieties are principally grown, and the yields obtained depend upon the previous preparation of the land and its treatment for a series of years. Where the land has been properly manured with stable manure, where lime has been applied at least once in the rotation, where a regular rotation of crops has been practiced for a considerable period of time, the yields of shelled corn range from 50 to 80 bushels per acre. The latter yield, of course, is only obtained by the best farmers under the most favorable circumstances. It is probable, however, that the average yield for the type upon well-tilled areas will be in excess of 50 bushels per acre. Excellent fields of corn grown upon the Sassafras silt loam in northern Delaware are shown in Plate VI, figure 2, and Plate VII, figure 1. Corn is grown not only for the shelled grain but also for silage purposes, particularly in southern New Jersey. Yields of silage corn frequently exceed 12 tons per acre, although the ordinary yield may be stated as from 10 to 12 tons.

Winter wheat is more extensively grown upon the Sassafras silt loam than any other grain crop. It is probable that nearly one-half of the cultivated area of the type is annually sowed to wheat.

In the more northern areas, especially in southern New Jersey, wheat yields from 20 to 25 bushels per acre, and yields of 35 and even 38 bushels are not infrequently obtained when the land is in the best condition and the season is favorable. In the eastern counties of Maryland and in Delaware yields of 15 to 25 bushels are secured, with an average production of about 18 bushels per acre. Such a wheat field is shown in Plate VII, figure 2. The yields in the southern counties of Maryland average 12 to 20 bushels on this soil. A good grade of hard winter wheat is produced, and even where the value of the land is unusually high the excellent yield of wheat and its good quality warrant its production upon the Sassafras silt loam.

Oats are not seeded extensively upon the Sassafras silt loam, but the yields per acre are good wherever the crop is grown. In some of the eastern Maryland counties yields of 40 to 50 bushels per acre of oats are reported, and it may be said that a yield of 35 to 45 bushels may normally be expected.

Both timothy and red clover are commonly seeded with one or the other of the small grain crops in regular rotation in order to furnish hay. In general, clover makes a good stand, especially if the land has been limed, and timothy is equally satisfactory. The mixed hay will yield from 1½ to 2 tons per acre, and where the soil is in particularly good condition this yield, even, may be exceeded.

These principal farm crops are usually grown upon the Sassafras silt loam in regular succession. There is some diversity in the order of the crop rotations, but in general the sod land is fall plowed and fitted in the succeeding spring for the production of corn. In this fitting the application of stable manure, either upon the sod before plowing or upon the plowed land before the planting of the corn, is the usual practice. In the latter case the manure is thoroughly harrowed in to the surface soil. Commercial fertilizers are also used in connection with the stable manure and a complete fertilizer, carrying 3 or 4 per cent of nitrogen, usually about 4 per cent of potash, and 10 to 12 per cent of phosphoric acid, is quite commonly selected. The quantity applied varies considerably in different localities, ranging from 250 pounds an acre to as much as 500 pounds an acre in the more intensively farmed districts. Frequent cultivation of the corn during the growing season is the rule where the largest crops are obtained. Corn is usually followed by wheat either for one or two crops. The second crop of wheat is not infrequently displaced by oats. In either case the land is seeded to timothy and clover with the second crop of grain and remains in grass for two years or more.

In the Chesapeake Bay region, where the Sassafras silt loam is extensively developed upon both sides of the bay, a considerable canning industry has been developed. This type of soil has contributed largely to the maintenance of the industry through the extensive production of sweet corn and of tomatoes. The canning corn is picked in the husk and sold, usually by the ton, to the local factories. The yield varies from 2½ to 3½ tons per acre under normal conditions. Prices, of course, vary, but the crop usually brings in a cash return of $25 to $35 an acre. The blades and stalks remain as rough forage to be fed upon the farm, and constitute a valuable by-product to those farmers who feed beef stock or dairy cows.

Tomatoes are produced extensively on the Maryland-Delaware Peninsula, and around the head of Chesapeake Bay in general. The soil is usually prepared for tomato growing by the application of such stable manure as is available and by the application of a complete commercial fertilizer. The plants are set to be cultivated in both directions and are not supported in the field. Yields vary materially. Where the ground has not been occupied previously for the production of this crop the Sassafras silt loam has been known to produce 12 tons or more of tomatoes per acre. In general, average yields, however, run from 6 to 8 tons upon this type of soil. The tomatoes are well known for quality and flavor, but constitute a late crop suitable for canning purposes rather than an early crop for market shipment.

The medium to late summer crop of Irish potatoes is also largely produced upon the Sassafras silt loam, both in southern New Jersey and upon the Maryland-Delaware Peninsula. The preparation of the land does not differ materially from that of the preparation for corn, although spring plowing is possibly more generally practiced for the potato crop. In the fertilization commercial fertilizer is used in larger quantities, applications of 1,000 pounds or more per acre being made by the best growers. A fertilizer high in potash content is usually employed. The yields vary from about 100 bushels per acre for the early crop to more than 200 bushels for the later crop in a favorable season.

Locally, both in southern New Jersey and on the Delaware-Maryland Peninsula, asparagus is produced to a considerable extent upon the Sassafras silt loam. The beds are long-lived and productive, but the asparagus, although excellent in quality, is not ready for marketing as early in the spring as the crop which is grown upon the more sandy soils.

The Sassafras silt loam was at one time extensively used on the Maryland-Delaware Peninsula for the production of peaches, and proved its value for this crop. Owing to the invasion of certain diseases many orchards have been cut out and their area is at present devoted to the general farm crops.

Recently the Sassafras silt loam has been extensively planted to pears, the Kieffer being the variety usually selected. The Kieffer is fairly resistant to blight, makes a strong growth, and usually gives a heavy yield. In both Maryland and Delaware thousands of bushels of Kieffers are annually canned in the local canneries. A considerable proportion of this crop is produced upon the Sassafras silt loam. A young orchard of Kieffer pears is shown in Plate VIII, figure 1.

The Sassafras silt loam is undoubtedly one of the best soils for apple production in the Maryland-Delaware Peninsula and in southern New Jersey. Several varieties are adapted to this type, but it is probable that Winesap, Stayman Winesap, Paragon, and Grimes Golden are best suited for this particular soil, under the climatic conditions existing in those sections of New Jersey, Pennsylvania, and of the Chesapeake Bay region where the type is developed. Wherever apples are to be planted upon this type the site should have some elevation and good natural drainage, both for water and for air.

Where the Sassafras silt loam is encountered in southern Maryland a considerable amount of the Maryland pipe-smoking tobacco is still grown upon it. The soil is generally considered rather too heavy and retentive of moisture to produce the best quality of leaf and the area planted to tobacco is gradually being reduced.

It will be seen from the foregoing discussion of the crop adaptations of this soil that it constitutes one of the best general farming types in the Atlantic Coastal Plain. In fact it is generally preferred above all others in the North Atlantic district for the production of the crops enumerated. It is a strong, fertile, well-drained, level-surfaced soil, and every acre of it has usually been cleared and placed under cultivation. In the hands of skillful farmers its crop-producing power has been increased from year to year until yields higher than the average for other soils in its localities are habitually produced. It is practically the only soil in the Atlantic Coastal Plain that compares favorably with the soils of the Limestone Valleys for the production of corn, wheat, and grass. It is one of the best soils in the Coastal Plain for the production of apples, pears, and peaches. It is well suited to the production of Irish potatoes, and of tomatoes and sweet corn for canning purposes. Its improvement may easily be accomplished through the restoration of organic material to the surface soil, aided by the application of lime.

As a natural consequence of the suitability of the Sassafras silt loam to the production of corn, oats, the grasses, and the leguminous forage crops, the type is one of the best soils in the North Atlantic Coastal Plain to serve as a basis for the establishment of the dairy industry. An excellent dairy herd on the Sassafras silt loam is shown in Plate VIII, figure 2. Where the price of land is high, ranging from $65 to $100 or more an acre, the business should be run upon a decidedly intensive basis. Pasturage should only constitute part of the regular rotation, and no land of this type should be set aside as permanent pasture. It is possible so to arrange the crop production of a farm upon the Sassafras silt loam that the corn silage and corn for the grain, peas, oats, and barley as soiling crops, rye or winter wheat as an early soiling crop, and the mixed grasses, cowpeas, crimson clover, crimson clover and rape, or even alfalfa may all be produced for forage purposes. The capability of producing these crops, taken together with good transportation facilities and the abundance of fresh pure water throughout the region, renders the soil ideal as a basis for dairying and stock raising.

Wherever rough land or pasture land of lower value is included in a farm made up principally of the Sassafras silt loam, sheep raising is also a profitable industry. The keeping of sheep in connection with the dairy industry has proved profitable in several locations.

CROP USES AND ADAPTATIONS.

All of the soils of the Sassafras series occur within a region characterized by a medium to long growing season, an abundant rainfall for the production of the majority of field crops, and generally

by a topography which permits of the cultivation of a large proportion of the land surface. In consequence of these natural advantages, a relatively high proportion of the total area of each of the soils of the series has been brought under different forms of agricultural occupation.

The crops grown and the systems of agriculture followed vary in different regions with variations in the character of the soil and with differences in the market and transportation conditions. It is also true that traditional forms of agriculture have to some degree influenced the characteristic crop production of some areas where these soils occur.

If consideration is given to the total acreages occupied by the chief crops grown upon the soils of this series it is probable that the areas given to corn, wheat, and hay and forage crops greatly exceed the areas devoted to all of the special crops combined. When the total value of the different crops is considered, the special crops take high rank, although the regions of their production are decidedly limited by market demands and the facilities for transportation.

The area occupied chiefly by the soils of the Sassafras series may, for convenience, be divided into several districts, within which major differences in cropping are characteristic.

On the western end of Long Island the area devoted to the production of miscellaneous vegetables as truck and market-garden crops exceeds that given to any other crops. The area planted to Irish potatoes is second in importance. Relatively small areas are devoted to hay and forage and to the cereal grains. Among the latter, corn predominates. When consideration is given to the value of the product, it may be said that the combined values of the miscellaneous vegetables and potatoes amount to considerably more than one-half of the total value of crops grown.

Because of the immediate proximity of this section to the great metropolitan markets, and because of the existence of rapid means of transportation to market and of a large mileage of good roads, the special forms of agriculture have largely supplanted the older systems of grass and grain growing, and the soils of the Sassafras series on Long Island have become special crop soils wherever they are so situated as to be used for any agricultural purpose.

The market-garden and truck farms on the western end of Long Island are usually of small size, and they are laid out in plots of small acreage, upon which a constant succession of vegetables is kept growing. It is the aim of the market gardener to keep the land constantly occupied during the growing season. In the early spring kale, spinach, and rheubarb are marketed. Later onions, radishes, and lettuce are sold. Their place is taken by early peas, sweet corn, and early potatoes. Later in the season crops of tomatoes and cab-

bage are grown. Kale and spinach are also planted for a late fall and early winter crop.

A large part of the market-garden crops grown within a radius of 25 to 30 miles of the city markets is transported to them by specially constructed two-horse market wagons. The vegetables are usually picked in the afternoon, transported to market during the night, and the produce sold on the wholesale market in the early morning. The direct sale of vegetables to the consumer is only undertaken by a very few growers.

The chief specialization in cropping with reference to soil adaptations in this district consists in the selection of the Sassafras sand for the growing of the extra early market garden crops, wherever it is available for such uses. The Sassafras gravelly loam is also used for market gardening and trucking, but its special value as an early Irish potato soil has led to its extensive use for the growing of that crop. It is probable that a large part of the potato crop grown on Long Island is produced on this soil.

There is such a demand for every acre suited to the growing of the different special crops that the truckers utilize the available land for the crops which their experience proves to be profitable, depending upon special skill in soil manipulation to a large degree for their success in crop production. The opportunities for soil selection for special crops is, therefore, somewhat limited or obscured.

The belt of territory in central New Jersey which is chiefly occupied by the soils of the Sassafras series is also well located with respect to great city markets and well provided with means of transportation. Within this region there is quite a wide variety in the character of the available soil types and the different uses of the soils of the Sassafras series for characteristic cropping systems is rather clearly marked.

Upon the heavier soils, especially the Sassafras silt loam, the growing of hay and forage and the production of corn and wheat constitute the chief industries so far as acreage occupied is concerned. Excellent yields are obtained and the farming tends toward a rather intensive form of grain and grass production, generally diversified by the growing of one or more special crops for cash sale. Early Irish potatoes are most generally grown for this purpose, with tomatoes for market probably second in importance. Dairying is carried on to some extent for the production of market milk.

The more sandy soils, such as the Sassafras sandy loam, fine sand, and sand, are much more completely occupied for special forms of crop production. This arises both from the fact that they are naturally well suited to the uses of the market gardener and trucker, and also from the fact that the larger areas of these types are unusually well situated with respect to market and transportation.

facilities. Considerable areas of all of these soils are found along the low forelands adjacent to the Delaware River and Bay within easy hauling distance of the Camden and Philadelphia markets, or else in such positions that rail transportation is available. Other large areas of these types lie along the main lines of rail communication between Philadelphia and New York, and are extensively utilized for special crop growing. Early Irish potatoes occupy the largest acreage given to any one crop. Those grown upon the Sassafras sandy loam, fine sand, and sand give fair yields of potatoes of good quality at a period when the southern New Jersey region can occupy the city markets between the shipments from points farther south and those from Long Island. The crop is planted early, early varieties are chosen, and the first shipments to market are frequently made by the middle of July. The movement of the crop from the more sandy soils continues until about the 1st of August. It is usually succeeded by shipment from the heavier soil types, especially from the Sassafras silt loam. This later crop is marketed from about the first to the middle of August. The dates of marketing vary with seasonal differences.

The production of sweet potatoes is decidedly localized and approximately one-half of the entire acreage grown in New Jersey is produced in Gloucester and Salem Counties, chiefly upon the Sassafras sand and fine sand. The special value of these types for sweet-potato production is well understood. They constitute warm, well-drained soils upon which good average yields are secured, and the potatoes are of excellent quality.

The miscellaneous vegetables occupy a considerable acreage upon all the soils of the Sassafras series in this region. They are most extensively grown upon the Sassafras sand, fine sand, and sandy loam where these occur within short distances of transportation facilities especially along the Delaware River south of Trenton. Tomatoes for market shipment are most extensively grown. The sandy soils produce moderate yields of early tomatoes while the Sassafras silt loam gives a somewhat larger yield but a later crop. Watermelons, cantaloupes, sweet corn, early peas, and beans, egg plant and asparagus constitute the other crops chiefly grown upon the more sandy soils of the Sassafras series in this region. Strawberries and other small fruits are also grown.

The greater part of the special crop production is carried on upon small farms which are intensively tilled to these crops. The fertility of these sandy soils is maintained by the use of large amounts of stable manure shipped into the district from the cities and supplemented by heavy applications of special commercial fertilizers. This is shown in Plate IX. A succession of market garden and truck crops is practiced rather than a crop rotation. Usually cover

and forage crops are grown upon a portion of each farm while a limited area may be given to grain.

In general it may be said that the adaptation of crops to soils and a consequent adoption of different farming systems have been very well worked out in the areas in New Jersey where the soils of the Sassafras series chiefly occur. The heavier, more retentive Sassafras silt loam is chiefly used for growing hay and forage crops, corn, Irish potatoes, and tomatoes. A supplementary dairy business is locally developed to a limited extent upon this soil. Its characteristic form of agriculture is diversified general farming.

The more sandy members of the series are utilized for special crop production wherever marketing facilities are available. Early Irish potatoes, early tomatoes, sweet potatoes, watermelons, and cantaloupes constitute the chief crops grown but a wide variety of other truck crops is also produced.

The extent to which these crops are established in this district is well shown by the fact that the five counties of Burlington, Camden, Gloucester, Monmouth, and Salem produced a total value of $8,559,567 of vegetables in 1909 or considerably more than one-half of the value for the entire State of New Jersey. This also amounted to nearly one-fifth of the total value of all crops produced in the State. In these five counties the value of all vegetables amounted to approximately one-half of the total value of crops grown.

On the Maryland-Delaware peninsula there is a rather striking adaptation of the cropping systems to the different classes of soils.

The northern portion of the peninsula, from the Piedmont border southward to the Choptank River, is dominated by the heavier soil types of the Sassafras and other series. The Sassafras silt loam and loam occupy extensive upland tracts in New Castle County, Del., and in Cecil, Kent, Queen Annes, and Talbot Counties, Md. In this section the farms are large, the fields are level and easy of tillage, and drainage is fairly well established. In consequence of these natural advantages the typical agriculture consists of the growing of the cereal grains and hay. A study of the acreages devoted to the principal farm crops shows that wheat occupies the chief areas in these counties, while corn is second and hay and forage crops are third in rank. The crop rotation most commonly employed is the 3-year rotation of corn, wheat, and hay, but a 5-year rotation is also used where wheat and hay are repeated before corn is again grown. Some farmers still follow wheat with corn without seeding to any grass crop.

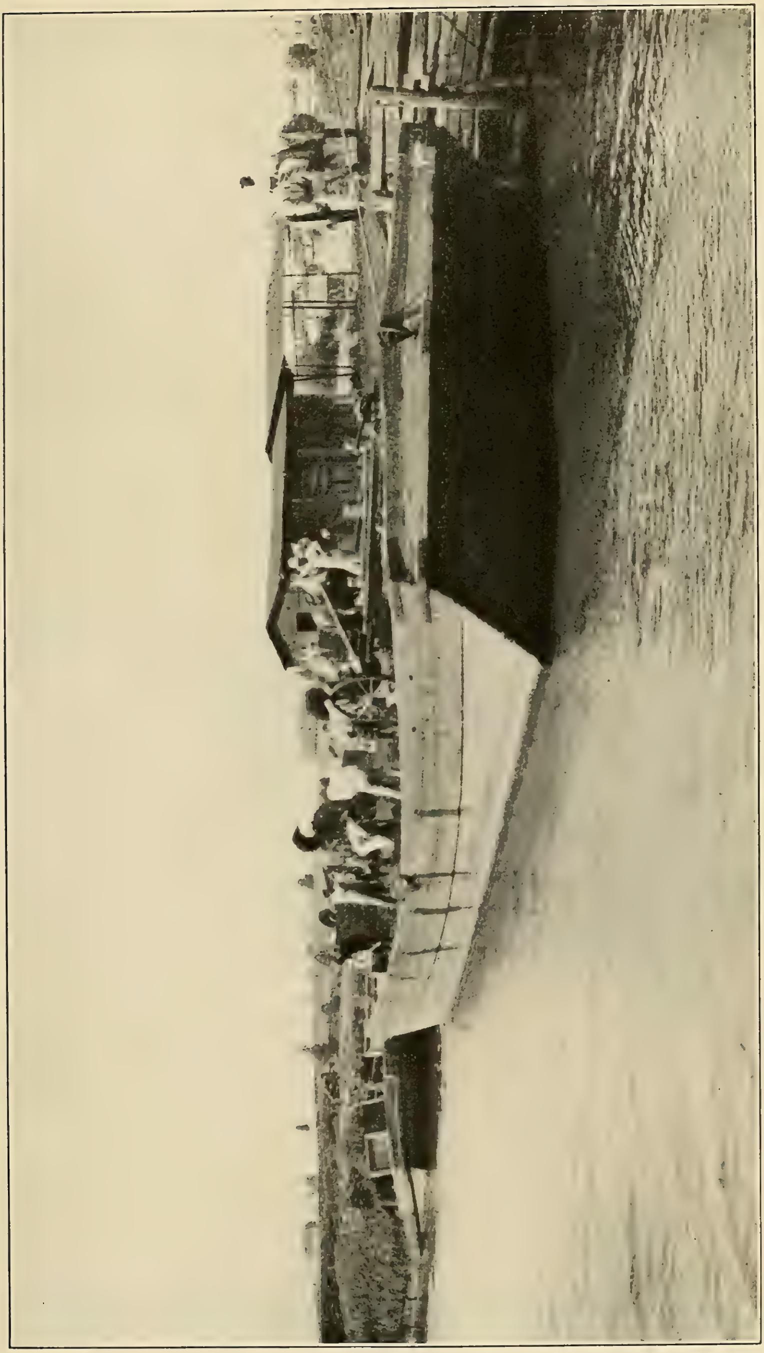
Tomatoes constitute the chief special crop of this section. They are grown for local canning factories or for shipment to others in near-by localities. The late crop for canning produces good yields

FIG. 1.—CORN GROUND CLEARED TO PREPARE FOR WINTER WHEAT, SASSAFRAS SILT LOAM, NORTHERN DELAWARE.

FIG. 2.—A DELAWARE HOMESTEAD AND WHEAT FIELD ON SASSAFRAS SILT LOAM, EASTERN DELAWARE.

FIG. 1.—KIEFFER PEAR ORCHARD ON SASSAFRAS SILT LOAM. A COMMON SIGHT ON THE MARYLAND-DELAWARE PENINSULA.

FIG. 2.—A DAIRY HERD ON SASSAFRAS SILT LOAM IN CENTRAL DELAWARE.



CITY STABLE MANURE SHIPPED BY SCOWLOADS TO THE TRUCK FARMS OF SOUTHERN NEW JERSEY.

upon these heavier soils, although early tomatoes for market are not so successfully grown.

Sweet corn is also grown for canning and Irish potatoes are produced for home use and, to a limited extent, for shipment.

The dairy industry is becoming established in some localities and milk and cream are shipped to market or butter is made at creameries. Some beef cattle are fattened for home use and for local markets. Swine are quite generally kept in small numbers, but chiefly for domestic supply or for the local markets. Some sheep are kept. It is probable, however, that poultry raising is the most important form of animal production for sale.

When the excellent yields of corn and grass secured from these heavier soils is considered it is noteworthy that the different forms of animal production have not become more generally adopted.

The southern and southeastern portion of the Maryland-Delaware peninsula is generally occupied by the more sandy members of the Sassafras series and by soils of other series. The Sassafras sandy loam predominates in southern Kent County, Del., and in portions of Sussex County. The Sassafras sand and loamy sand are also important soils south of the Choptank River. Upon these more sandy soils the production of wheat is not so successful as upon the loam and silt loam of this series, and the acreage given to corn greatly predominates. A smaller production of grass and forage crops is also grown and the special crops become of considerable importance both in total area and in gross value of the product. Tomatoes are extensively grown for canning and to some extent for market shipment. Sweet potatoes are an important crop, while Irish potatoes for the city markets are coming to be extensively grown.

The production of tree fruits is of considerable importance, and the Sassafras sandy loam is recognized as one of the best soils of the section for growing apples, pears, and peaches. Grapes are also becoming established upon this type in Delaware.

Considerable areas of small fruits, particularly strawberries, are grown and the earlier varieties are produced on the Sassafras sand and sandy loam. The later varieties are more commonly grown on the soils of the Portsmouth series.

The introduction of the special crops in this section has led to the more complete occupation of the sandy soils for agricultural purposes, and they are highly esteemed for the purposes of fruit growing and trucking.

In general, the crop adaptations of the different soils of the Sassafras series are well understood and quite generally followed in the farm practice of the Maryland-Delaware peninsula. The heavier soils are utilized for grass and grain production; the more

sandy soils are little used for wheat or other small grains, but are largely planted to corn and to special vegetable and fruit crops.

Systematic crop rotations are quite generally employed, use is made of leguminous crops for forage and for green manuring, and a large amount of commercial fertilizers is annually used both by the general farmer and the truck and fruit grower. Broad, nearly level stretches of territory make the use of the larger farm implements possible and profitable. The region is fairly well equipped with work stock and machinery and a large percentage of the land area is tilled.

The agriculture on the soils of the Sassafras series in southern Harford and Baltimore Counties, Md., consists chiefly of the production of corn, wheat, and forage crops. The growing of sweet corn and tomatoes for canning factories is also an important industry.

In the southern Maryland counties there is again a considerable difference in the cropping practices of the different sections, varying with the character of the soils and with the distance from market. In the northern part of Anne Arundel County the more sandy members of the Sassafras series occur extensively and they are used for the production of vegetables and small fruits to a very considerable extent. In this county the area devoted to vegetable growing nearly equals the area in corn and far exceeds the acreage given to any other crop. Proximity to market strongly influences the class of farming since the soils of the Sassafras series in the southern part of the county are chiefly used for the growing of corn, tobacco, wheat, hay, and forage. While the soils of the Sassafras series occur only to a limited extent in other parts of southern Maryland, they produce fair average yields of corn, wheat, and forage crops, while tobacco is also grown extensively upon the more sandy members of the series.

South of the Potomac River the soils of this series are chiefly used for the production of corn and wheat. Forage crops are also grown, while areas suitably located are used to some extent for growing tomatoes for market and for canning and for the production of other vegetables.

SUMMARY.

The soils of the Sassafras series are distinguished by the yellow or brown color of the surface soils, by the yellow or reddish-yellow color of the subsoils, and by the prevalence of an underlying layer of gravel or of gravelly sand at depths ranging from 2 to 6 feet or more.

They consist of water-laid materials chiefly formed as marine and estuarine terraces, but including some areas which were formed by the deposition of glacial outwash materials.

These soil materials thus comprise débris of glacial origin, sediments derived from the Appalachian and Piedmont soil provinces, and reworked material from the older Coastal Plain deposits which they overlie.

The soils of the Sassafras series are confined in their distribution to the northern portion of the Atlantic Coastal Plain, extending from the southern end of the Chesapeake Bay region through central and southern New Jersey to the western end of Long Island, N. Y.

Within this region they occupy low-lying terraces which border the ocean and the chief tidewater estuaries, lying at altitudes which range from approximately sea level to elevations of 200 feet or more. In general the surface of the different types is nearly level to gently undulating, although some small hills and eroded areas are found.

The drainage of the soils of the Sassafras series is generally good and only the more level areas and those remote from stream channels are decidedly in need of artificial drainage.

In texture the soils of the Sassafras series range from a gravelly loam through sands and sandy loams to a heavy silt loam. These differences in soil texture give rise to differences in the crops which may be grown to best advantage upon the different types in the series.

The Sassafras sand, loamy sand, and fine sand are best suited, under favorable circumstances of markets and transportation, to the production of vegetable and fruit crops.

The Sassafras sandy loam is the coarsest-grained type suited to general farm crops and it is also well suited to the growing of many of the fruit and truck crops.

The Sassafras loam and silt loam constitute excellent soils for the growing of corn, wheat, and hay and are also used for the planting of orchards of apples and pears.

The character of agriculture conducted on the different types of the series differs both with the texture of the soil and with the accessibility to markets and to transportation. Areas of the more porous soils in the vicinity of large city markets are largely occupied for market-gardening and trucking, as in southern New Jersey, portions of Delaware, and some sections of Maryland. Areas not thus favorably located are used to a small extent for the production of staple crops with only moderate yields.

The more dense and retentive types are chiefly used for the growing of grain and grass. Corn and wheat are the chief grain crops. Mixed timothy and clover and clover alone are grown for hay. Dairying and stock raising are conducted to a limited degree upon portions of these soils, particularly in southwestern New Jersey and in the northern part of the Maryland-Delaware peninsula. The

Maryland type of pipe-smoking tobacco is grown on the fine sandy loam, the loam, and to some extent on the silt loam in the southern counties of Maryland.

The farm equipment of buildings, stock, and implements on the different types of the Sassafras series varies with the character of the farming operations and to some extent with the type of soil. The truck and fruit farms on the more sandy types are usually well provided with substantial farm buildings, light, but effective work stock and tillage implements, and the special equipment needed for the conduct of intensive farming operations. The heavier soils of the series are usually equipped with adequate dwellings and barns and with somewhat heavier work stock and implements for grain raising.

The chief requirements for the improvement of crop yields upon the different types of the series are the more extended use of stable manure, supplemented with the plowing under of green-manuring crops; the use of lime in some form, particularly in conjunction with the growing of the leguminous forage and green-manuring crops; the adoption in some sections of a crop rotation which shall provide for the alternation of grass crops with the prevalent system of grain growing; and local underdrainage on small areas of the heavier textured types.

The soils of the Sassafras series constitute a group of soils which are suited to intensive tillage for the growing of market garden and truck crops upon the more sandy types while the heavier types constitute the best soils for the production of the staple crops to be found within the northern portion of the Atlantic Coastal Plain.

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(PROFESSIONAL PAPER.)

CACTUS SOLUTION AS AN ADHESIVE IN ARSENICAL SPRAYS FOR INSECTS.[1]

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INTRODUCTION.

In the application of arsenical sprays against insects with biting mouth parts the object in view is, of course, to protect the plant or plants from insect ravages by poisoning the foliage, so that the insects will, in feeding, take into their system enough of the poison to produce death. Some arsenicals, because they possess a higher percentage of free arsenic, act more quickly in this direction than others, but these are, as a rule, injurious to most plant foliage, unless mixed with some agent that will counteract the free arsenic and produce a more uniform distribution on the plants sprayed. Arsenicals containing a high percentage of arsenious oxid generally possess only slight adhesive powers and after a heavy dew or light rain are washed from the foliage.

Certain crops demand very prompt protection from the ravages of biting insects; otherwise severe losses are almost certain to be incurred, and to insure the preservation of the crop concerned it is highly important that a poison with some lasting qualities, as well as one quick in action, be applied. Thus it follows that an arsenical must adhere to the foliage if the most favorable results are to be realized.

In 1913 and 1914 some experiments were conducted for the purpose of discovering a good adhesive which could be obtained easily and at little expense to the grower. This adhesive has been found in a cactus that flourishes in the Southwest. The variety which was most extensively used in the following experiments, and

[1] This bulletin describes the use of cactus solution as an adhesive in the application of arsenical sprays against the belted cucumber beetle. It is applicable to regions where prickly pear is easily obtainable and for the treatment of insects of related habits, such as the striped and twelve-spotted cucumber beetles, etc.

one of the most abundant of the many species to be found in the lower Rio Grande Valley, is *Opuntia lindheimeri* Engelm., commonly known as the "prickly pear." This plant produces a fruit that is available about one month in each year and one of which the natives are especially fond. Further, the plants themselves furnish food to many domestic animals and, it is claimed, prevent many cattle from dying during severe droughts because of their highly watery composition. Many ranchmen protect their cacti during a wet season and save them against the time of drought. A gasoline torch, manufactured especially for the purpose, is used to burn off the spines, and as soon as this burner is put into operation cattle, recognizing the peculiar noise, come at once to obtain the food thus rendered available.

The prickly pear, besides being high in fluid content, is very mucilaginous and is invariably used by Mexicans in the manufacture of whitewash, to promote adhesiveness. The cactus is sliced the evening previous to the application and placed in the water or in the lime mixture, where it remains for several hours. The whitewash is then ready for use. The utilization of cactus in whitewash thus suggested to the writer its availability as a factor in promoting adhesion in poisonous sprays.

EXPERIMENTAL WORK WITH CACTUS.

EXPERIMENTS WITH ZINC ARSENITE.

On March 23, 1913, 20 pounds of cactus were sliced lengthwise and immersed overnight in 50 gallons of water. The next morning 2 pounds of zinc arsenite in paste form were added, and after a thorough mixing spraying was commenced on sugar beets which were being injured by the belted cucumber beetle (*Diabrotica balteata* Lec.).[1]

A previous experiment demonstrated that cactus yields a higher percentage of mucilaginous matter if sliced at right angles to the spines, and, moreover, the time required for preparation is materially shortened by this method. It is best, however, to cut the larger pads both ways, since, owing to the cellular structure of the pads, this method insures a more copious and rapid flow of the juices. The result obtained from the use of the spray, at the rate of 20 pounds of prepared cactus to 50 gallons of water, was gratifying; the spray not only adhered to the foliage better, but spread more uniformly over the surface of the leaves. The quantity of cactus required to

[1] Accounts of this species, by Dr. F. H. Chittenden and Mr. H. O. Marsh, have been published in Bulletin No. 82, Part VI, Bureau of Entomology, U. S. Departemnt of Agriculture, pages 69–71 and 76–82, December 8, 1910. These include illustrations of the stages, notes on life history, lists of food plants, and technical descriptions of the different stages.

make 20 pounds is comparatively small. The results of this spraying operation were favorable, as the number of beetles present four days later did not exceed 30 per cent of the original number, and a majority of these had just arrived from near-by breeding quarters.

In the next experiment 10 pounds of cactus were used in combination with 3 pounds of zinc arsenite and 50 gallons of water. As before, the cactus was sliced and placed in water the evening previous to spraying, and the following morning the solid particles were thrown out before the poison was added. This spraying operation, with but 10 pounds of cactus, gave good results, but the spreading quality of the material was not as good as in the first experiment, in which 20 pounds of cactus were employed.

In the next experiment, on April 3, 15 pounds of cactus were used with 3 pounds of zinc arsenite and 50 gallons of water. In this case the poison appeared to adhere and spread as well as when 20 pounds of the cactus were used. It thus appeared that 15 pounds of the cactus with spines[1] would be about the proper proportion to use with 50 gallons of water in future work.

The following table shows the mortality of *Diabrotica balteata* placed on an encaged sugar-beet plant sprayed with zinc arsenite at the rate of 3 pounds to 50 gallons of water plus 15 pounds of prepared cactus:

TABLE I.—*Experiment No. 10.—Cactus as an adhesive in combination with arsenite of zinc, Brownsville, Tex., 1913.*

Date.	Beetles present.	Living.	Dead.	Feeding.	Not feeding.
Mar. 17	5	4	1	4	1
Mar. 18	5	3	2	3	2
Mar. 19	5	3	2	3	2
Mar. 21	5	1	4	1	4
Mar. 22	5	0	5	0	5

The beetles were placed on the sprayed plant at 6.30 p. m., March 15, but during several cool days which followed they were quite inactive and probably fed but little. Cactus was tested in the insectary as an adhesive before experiments were conducted in the field, to insure the absence of any inopportune chemical reaction that might injure the plants. This experiment demonstrated that in approximately six days after spraying 99 per cent of the beetles succumbed to the poison. Simultaneously with the foregoing experiment another

[1] Cactus with spines is preferable to the spineless varieties; in fact, the spiny variety appears to be nearly one-third richer in gluten. The Dairy Division of the Bureau of Animal Industry has been conducting some cactus-feeding experiments for dairy cows the past two years, and has made several analyses of both the spined and spineless varieties of cactus.

pot experiment was made, discarding cactus and using the same amount of arsenite of zinc. The following results were obtained:

TABLE II.—*Experiment No. 11.—Arsenite of zinc without cactus as an adhesive, Brownsville, Tex., 1913.*

Date.	Beetles present.	Living.	Dead.	Feeding.	Not feeding.
Mar. 17	7	6	1	6	1
Mar. 18	7	4	3	4	3
Mar. 19	7	4	3	2	5
Mar. 21	7	3	4	3	4
Mar. 22	7	3	4	1	6

It will be noticed here that at the end of the sixth day the mortality was much under that of experiment No. 10. The plants in both experiments were sprayed thoroughly, but the latter spray did not spread as well as the former. In the next experiment cactus was again used at the rate of 20 pounds to 50 gallons of water. The same amount of zinc arsenite was used in this experiment, or 3 pounds to 50 gallons of water. Table III shows the number of deaths on each date.

TABLE III.—*Experiment No. 12.—Cactus as an adhesive in combination with arsenite of zinc, Brownsville, Tex., 1913.*

Date.	Beetles present.	Living.	Dead.	Feeding.	Not feeding.
Mar. 17	14	8	6	6	8
Mar. 18	14	3	11	2	12
Mar. 19	14	3	11	1	13
Mar. 21	14	0	14	0	14
Mar. 22	....	0	....	0	....

The beetles were placed on the poisoned sugar beet at 6 p. m., March 15, and in 36 hours nearly all of them were dead.

EXPERIMENT WITH PARIS GREEN AND LIME.

In the next pot experiment Paris green was used in place of zinc arsenite and at the rate of one-half pound to 50 gallons of water plus 2 pounds of lime. The plant was sprayed on March 17, and as soon as the poison was dry on the sugar beet the beetles were liberated inside the cage. Table IV sums up the results.

TABLE IV.—*Experiment No. 13.—Cactus as an adhesive with Paris green and lime, Brownsville, Tex., 1913.*

Date.	Beetles present.	Living.	Dead.	Feeding.	Not feeding.
Mar. 18	10	10	0	6	4
Mar. 19	10	2	8	2	8
Mar. 21	10	0	10	0	10
Mar. 22	10	0	10	0	10

The cucumber beetle appeared, as will be seen from the foregoing table, to succumb more readily to the Paris-green spray than to any one of the former sprays of zinc arsenite. In the field experiments there was not much difference, though the zinc arsenite gave more favorable results in that it lasted longer. The dews in the lower Rio Grande Valley are usually heavy ones, which would naturally reduce the effectiveness of the Paris-green application. But, as already shown, in the pot experiment the results appeared much more quickly than with the other sprays.

UNSATISFACTORY RESULTS WITH LEAD ARSENATE.

Since the experiments with cactus as an adhesive and a spreader for zinc arsenite and for Paris green and lime had resulted so favorably, not only in increasing the adhesiveness of the spray, but also in the destruction of the beetle, it was decided to try it in combination with lead arsenate. The cactus was placed in a barrel of water about 12 hours before the arsenate of lead was added. A few minutes after adding the lead arsenate the formation of a precipitate was observed. In an hour's time a cottony scum had formed on the surface and appeared fairly well distributed throughout the mixture. In the meantime spraying had been going on, but with little success, as this semiliquid matter clogged the nozzles. In about two hours' time the precipitation was more complete and the solution was discarded, since its consistency rendered it useless for spraying purposes. Alkalinity of the water was at first suspected, and rain water was substituted, but with the same results, so that no further attempt was made to use the cactus with lead arsenate. The lead arsenate employed was air-dried, having been formerly paste which had dried out in an open keg; but no doubt even with fresh arsenate of lead the same precipitation would have taken place, as the air-dried arsenical had been used successfully without the cactus and had remained in solution, although it did not adhere well.

In experiment No. 14 (Table V) arsenate of lead was employed at the rate of 3 pounds to 50 gallons of water. As the potted plant was quite small, there was not sufficient foliage to support a great number of beetles, and on April 4, at 6 p. m., six belted cucumber beetles were placed on the plant.

TABLE V.—*Experiment No. 14.—Cactus as an adhesive with arsenate of lead. Brownsville, Tex., 1913.*

Date.	Beetles present.	Living.	Dead.	Feeding.	Not feeding.
Apr. 6	6	5	1	4	2
Apr. 7	6	5	1	4	2
Apr. 8	6	4	2	3	3
Apr. 9	6	2	4	2	4
Apr. 11	6	0	6	0	6

The time required to kill all of the beetles placed on the sprayed plant was approximately six days, provided all specimens began feeding immediately after being placed on the poisoned plant.

In the next experiment $2\frac{1}{2}$ pounds of arsenate of lead were used to 50 gallons of water. The host plant was spinach that had been growing in the pot for some time. The spraying was done during the morning of April 14, and at 4 p. m. on the same date, after the poison had dried, 10 belted cucumber beetles were placed inside the cage and on the plant where possible. Table VI shows the mortality:

TABLE VI.—*Experiment No. 15.—Cactus as an adhesive with arsenate of lead, Brownsville, Tex., 1913.*

Date.	Beetles present.	Living.	Dead.	Feeding.	Not feeding.
Apr. 16	10	9	1	7	2
Apr. 17	10	8	2	5	3
Apr. 24	10	2	8	0	8

The spray here used was not so effective as in experiment No. 14, the mortality being only 80 per cent at the end of nine days. The plant died from some cause about the 24th of April, and probably very little feeding was done during the last few days the plant lived after being sprayed.

FURTHER EXPERIMENTS.

The results obtained in the foregoing experiments had been so favorable that further experiments on a larger scale were commenced. Several thousand pounds of the prickly pear were used in the work, and as the regular "pear burner," or torch, was employed to singe the spines from the pads, they could now be handled with some comfort. The work has been conducted in a small way and on a large scale with about the same degree of success. It requires only a short time to burn the spines from enough cactus to make a sufficient amount of adhesive material for several thousand gallons of spray mixture.

The list of insecticides that have been employed in combination with cactus as an adhesive includes Paris green, lead chromate, zinc arsenite (in both paste and powder forms), lead arsenate, ferrous arsenate, and iron arsenite. The preceding pages give an account of experiments with zinc arsenite in the paste form, Paris green, and lead arsenate in the paste form, while the experiments that follow will include zinc arsenite in the powder form, lead arsenate in paste form, ferrous arsenate, and iron arsenite, the last two used in the powder. The powdered zinc arsenite gave excellent results in every instance when used in combination with cactus water, and the mortality was in some cases higher than when three times the weight in

paste form was used. Very favorable results were obtained with ferrous arsenate in most cases, while the results with iron arsenite were not quite so good. The following tables give results of the experiments conducted in the insectary with each of the arsenicals here mentioned.

On March 1, 1914, a cabbage plant was sprayed with ferrous arsenate at the rate of 1 pound to 40 gallons of water, and as soon as the poison had dried on the leaves, or at 6 o'clock p. m. the same date, four *Diabrotica balteata* were encaged on the plant.

TABLE VII.—*Experiment No. 16.—Cactus as an adhesive with ferrous arsenate, Brownsville, Tex., 1914.*

Date.	Beetles present.	Living.	Dead.	Feeding.	Not feeding.
Mar. 2	4	4	0	1	3
Mar. 3	4	4	0	0	4
Mar. 4	4	4	0	3	1
Mar. 5	4	4	0	3	1
Mar. 6	4	4	0	3	1
Mar. 7	4	4	0	2	2
Mar. 8	4	4	0	3	1
Mar. 9	4	4	0	2	2
Mar. 10	4	1	1	1	1

It will be seen from the foregoing table that the mortality was much too low to pay for applying the poison. It was observed that the feeding was light for four or five days after confinement. The solution did not adhere and distribute itself well enough to make a good spray.

About the same time that spraying was done on experiment No. 16 a second solution was made up, using the same amount of ferrous arsenate or 1 pound to 40 gallons of water. Eighty per cent of the water used was taken from a tank where two days previous $1\frac{1}{3}$ pounds of cactus to the gallon of water had been placed. This made an exceedingly glutinous solution which caused the liquid to spread uniformly as well as to adhere. On March 2 seven *Diabrotica balteata* were placed on the plant.

TABLE VIII.—*Experiment No. 17.—Cactus as an adhesive with ferrous arsenate, Brownsville, Tex., 1914.*

Date.	Beetles present.	Living.	Dead.	Feeding.	Not feeding.
Mar. 3	7	6	1	3	4
Mar. 4	7	6	1	6	1
Mar. 5	7	6	1	6	1
Mar. 6	7	6	1	4	3
Mar. 7	7	6	1	5	2
Mar. 8	7	6	1	4	3
Mar. 9	7	6	1	3	4
Mar. 13	7	5	2	1	6
Mar. 14	7	5	2	4	3

The death rate in this experiment was very low, which is accounted for to a certain degree by a decrease in the voracious appetite of the beetles, which were encaged on a cabbage plant. Feeding appeared to be more from the underside of the leaves, and usually the epidermis was left intact.

In the next experiment with potted plants spinach was substituted for cabbage, since it seemed preferable to the beetles, particularly as the cabbage plants had been growing for some time in the pots and had become more or less stunted and tough. In this experiment ferrous arsenate was used at the rate of 1 pound to 40 gallons of water, in which 40 pounds of cactus had been placed 72 hours previous. Table IX shows results and mortality. The plant was sprayed April 2, and on April 4 five beetles were liberated on the plant and covered with a lantern globe.

TABLE IX.—*Experiment No. 18.—Cactus as an adhesive with ferrous arsenate, Brownsville, Tex., 1914.*

Date.	Beetles present.	Living.	Dead.	Feeding.	Not feeding.
Apr. 4	5	5	0	4	1
Apr. 5	5	5	0	1	4
Apr. 6	5	5	0	0	5
Apr. 7	5	4	1	0	5
Apr. 8	5	3	2	0	5
Apr. 9	5	2	3	0	5

The results here were much better than in experiments Nos. 16 and 17, and the beetles appeared to succumb more readily, since they fed more rapidly.

On April 6 a spray was made up of ferrous arsenate, using 1 pound to 12 gallons of water in which 10 pounds of sliced cactus had been placed 48 hours previous to spraying, insuring thorough glutinous consistency in the spray mixture. Some spinach plants in pots were sprayed previous to spraying plats in the field. On April 13, or one week from date of spraying, six beetles were encaged on a plant and observed for 10 days. Table X shows the number of beetles that succumbed.

TABLE X.—*Experiment No. 18.—Cactus as an adhesive with ferrous arsenate, Brownsville, Tex., 1914.*

Date.	Beetles present.	Living.	Dead.	Feeding.	Not feeding.
Apr. 13	6	6	0	3	3
Apr. 14	6	4	2	4	2
Apr. 15	6	4	2	4	2
Apr. 16	6	4	3	3	3
Apr. 18	6	4	2	1	5
Apr. 20	6	3	3	2	4
Apr. 21	6	3	3	1	5
Apr. 23	6	3	3	0	6

This plant began to wilt and appear blighted on April 18, little feeding being done from that date, even though the poison had been on the plant for nearly two weeks. It is thought that a higher mortality would have occurred had the plant remained green and living.

An arsenate of lead spray was made, using the paste form at the rate of 4 pounds to 60 gallons of water. In this solution no cactus was used. On April 11 five beetles were placed on an encaged cabbage plant in the insectary that had been sprayed five days before. Table XI gives the final results.

TABLE XI.—*Experiment No. 20.—Arsenate of lead without cactus, Brownsville, Tex., 1914.*

Date.	Beetles present.	Living.	Dead.	Feeding.	Not feeding.
Apr. 13	5	5	0	4	1
Apr. 14	4	3	1	1	3
Apr. 16	4	3	1	1	3
Apr. 18	4	2	2	1	1

This spray did not adhere to the cabbage foliage as well as when cactus was used, and the beetles fed very slowly after the first two days of confinement. Better results were obtained in the field, as the beetles began feeding just after spraying, and where a partial uniform coating was secured the poison was effective. If the poison could be made to combine or mix with cactus water the results would undoubtedly be much better.

April 2 a solution was made up of iron arsenite, using 1 pound to 40 gallons of water. Some difficulty was experienced in bringing the poison into suspension, as it settled quite rapidly to the bottom of the barrel. April 4 another solution was prepared, using the same amount of poison to a given quantity of water, with the previous addition of cactus at the rate of 1¼ pounds to each gallon of water, in which salicylic acid had been used as a preservative to prevent fermentation of the cactus juice. As a check some potted cabbage plants were sprayed. On April 11 ten belted cucumber beetles were encaged on one of the cabbage plants that was sprayed April 4. Table XII gives the results.

TABLE XII.—*Experiment No. 21.—Cactus as an adhesive with iron arsenite, Brownsville, Tex., 1914.*

Date.	Beetles present.	Living.	Dead.	Feeding.	Not feeding.
Apr. 13	10	9	1	7	3
Apr. 14	8	7	1	7	1
Apr. 15	8	7	1	7	1
Apr. 16	2	1	1	1	1
Apr. 18	2	1	1	0	2

It is apparent that although the application had been made for more than a week, a sufficient amount of the arsenical remained to have some effect on the feeding of the beetles. A later experiment with iron arsenite showed the mortality of the beetles when they feed on the plant immediately after spraying has been done.

While spraying a plat of sugar beets at the South Texas Gardens on April 15 the writer also sprayed some plants in the insectary, using zinc arsenite in the powdered form. The cactus was used at the rate of 1.8 pounds to the gallon of water and the zinc arsenite at the rate of 1 pound to 64 gallons. The plants were sprayed on the morning of the 15th, and on April 16 eleven beetles were liberated inside the cage surrounding the plants.

TABLE XIII.—*Experiment No. 22.—Cactus as an adhesive with zinc arsenite, Brownsville, Tex., 1914.*

Date.	Beetles present.	Living.	Dead.	Feeding.	Not feeding.
Apr. 16	11	11	0	8	3
Apr. 17	11	10	1	9	2
Apr. 18	11	10	1	9	2
Apr. 20	11	4	7	4	7
Apr. 21	11	4	7	3	8
Apr. 23	11	1	10	0	11

This spray adhered and spread exceedingly well, although much less cactus could have been used with equal results. However, no precipitation was observed when the cactus was used at this strength.

In experiment No. 23 a potted sugar beet was sprayed April 11 with zinc arsenite (powdered) at the rate of 1 pound to 35 gallons of water, using three-fourths of a pound of cactus to each gallon of water, the cactus having been placed in the water four days before. Fermentation was prevented by the use of copper sulphate. On April 15 ten belted cucumber beetles were encaged on the plant.

TABLE XIV.—*Experiment No. 23.—Cactus as an adhesive with zinc arsenite, Brownsville, Tex., 1914.*

Date.	Beetles present.	Living.	Dead.	Feeding.	Not feeding.
Apr. 16	10	10	0	5	5
Apr. 17	10	10	0	5	5
Apr. 20	8	2	6	2	6
Apr. 21	8	1	7	1	7
Apr. 23	8	0	8	0	8

It will be observed that in this experiment less than half the quantity of cactus was used than was added in experiment No. 22, but the zinc arsenite was increased to nearly twice the amount used in the preceding experiment, and there was only a 10 per cent difference

in the mortality. The plants used were both sugar beets. The result of this experiment shows that by the use of cactus the lasting qualities of the poison on the plants may be greatly increased.

The spraying in experiment No. 24 was done at the same time as in experiment No. 22, 1 pound of zinc arsenite being used to 64 gallons of water but only one-third of a pound of cactus to each gallon, the glutinous matter having been extracted by soaking the cactus for four days in water. Salicylic acid was added as a preservative. The sugar beet was sprayed on April 15, and on April 16 five beetles were placed on the plant. April 17 one beetle was found dead and four still feeding. April 18 three had died from the effect of the poison and two were yet feeding. On April 20 all were dead. During the four days the beetles were encaged they appeared to feed very rapidly, as they had been confined for several days without food. This proves that 1 pound of powdered zinc arsenite with cactus to make it adhere is more effective than 2 pounds in the paste form and just as effective as 3 pounds in the paste form.

The plant in experiment No. 25 was sprayed with 1 pound of zinc arsenite to 35 gallons of water and at the same time as No. 23, on April 11, with the same quantity of cactus, but the beetles were not placed on the plant for six days after spraying. On April 17 three beetles were encaged, and by the 22d all were dead.

On April 5, after spraying a field plat of cabbage with ferrous arsenate, several plants were treated in the insectary. The strength used was 1 pound to 12 gallons of water. One pound of cactus was used to each gallon of water, the cactus water having been made 26 days when used. It was prepared on March 16 and sodium benzoate added as a preservative. On April 11 six beetles were placed on a cabbage plant covered by a lantern globe. Table XV gives the number of beetles that succumbed in a given period.

TABLE XV.—*Experiment No. 26.—Cactus as an adhesive with ferrous arsenate. Brownsville, Tex., 1914.*

Date.	Beetles present.	Living.	Dead.	Feeding.	Not feeding.
Apr. 13	6	6	0	4	2
Apr. 14	6	6	0	5	1
Apr. 15	6	6	0	5	1
Apr. 16	6	6	0	1	5
Apr. 17	6	3	3	2	4
Apr. 18	5	1	4	1	4
Apr. 20	5	1	4	1	4
Apr. 21	5	0	5	0	5

The beetles from some cause fed very sparingly the whole time they were encaged. Whether the poison was distasteful or the plant had become tough, could not be ascertained.

On April 4 a small plat of cabbage was sprayed with iron arsenite at the rate of 1 pound to 40 gallons of water. Two pounds of cactus were added to each gallon and the decoction was prepared on March 14 and 15. It was preserved with salicylic acid at the rate of $\frac{1}{4}$ pound to 50 gallons. It was quite difficult to bring the arsenite of iron into suspension. Thorough agitation was required to prevent it settling to the bottom of the tank. With a hand sprayer it is impossible to secure uniformity in the spray. Table XVI gives results with 10 beetles on one cabbage plant sprayed on April 4, the beetles being liberated on the plant April 11.

TABLE XVI.—*Experiment No. 27.—Cactus as an adhesive with iron arsenite, Brownsville, Tex., 1914.*

Date.	Beetles present.	Living.	Dead.	Feeding.	Not feeding.
Apr. 13	10	10	0	10	0
Apr. 14	10	9	1	8	2
Apr. 16	10	9	1	6	4
Apr. 17	10	9	1	6	4
Apr. 18	10	8	2	7	3
Apr. 20	10	8	2	4	6
Apr. 21	9	6	3	6	3
Apr. 23	9	5	4	5	4

Feeding was very heavy on this plant, which had been growing for some time in the pot and had been seriously attacked by aphides on two occasions. Iron arsenite has some value as an insecticide, but not as much as ferrous arsenate, even when properly made up, and unless an effort is made to apply it in uniform coating on the foliage it has little value as an insect destroyer.

CACTUS COMPARED WITH WHALE-OIL SOAP AS AN ADHESIVE.

On February 20, 1914, while conducting spraying experiments against the belted cucumber beetle and cabbage looper (*Autographa brassicæ* Riley) on cabbage on the farm of Mr. George Federhoff, near Brownsville, Tex., it was decided to make a comparison of whale-oil soap and cactus as adhesives, without considering the cost of the two products. One acre of cabbage was sprayed with 1 pound of zinc arsenite (in powdered form) to 60 gallons of water, with the addition of 35 pounds of cactus. The cactus was sliced and put in the water on February 19, and had given up its glutinous matter to the solution by the time spraying was begun the following day. This mixture spread and adhered exceedingly well. The next acre was sprayed with the same amount of poison, but whale-oil soap was substituted for cactus. This was done both for a comparison of adhesive qualities and to observe the effect of the soap on the cabbage aphis (*Aphis brassicæ* L.), as in several spots

in this acre the aphis was making its appearance. The soap was used at the rate of 3 pounds to 60 gallons of water. Very careful notes were made on the sticking qualities of the soap, and it was found that when compared at close range with the cactus spray the soap equalled the cactus in spreading power, although lacking in adherence. This information was obtained by observing sprayed plants with and without a lens. It was soon seen that the cactus spray adhered and dried on the foliage better than the soap spray. This favored the cactus, since the heavy dews in the Rio Grande Valley will wash poison having but slight adhesive qualities from the foliage in a short time.

COPPER SULPHATE AS A PRESERVATIVE FOR THE CACTUS.

On April 6, 1914, 50 pounds of cactus were cut into small pieces and placed in a barrel with 24 gallons of water, and on April 7, 1 pound of copper sulphate was dissolved in 4 gallons of water and added to the barrel which was numbered lot 6.

The solid portion of the cactus or prickly pear was removed before adding the copper sulphate. This made 28 gallons in solution. No chemical action was observed. The solution kept perfectly for about four weeks, when it had to be discarded to make room for other experiments. The temperature during this time averaged about 70° F.

COPPER SULPHATE USED WITH ZINC ARSENITE.

After using the copper sulphate as a preservative for the juice extracted from the prickly pear, the possibility of a chemical reaction upon the addition of the arsenical to the solution was tested. Upon the addition of powdered zinc arsenite at the rate of 1 pound to 60 gallons of water a slight chemical reaction was noticed, evidently the copper changing places with the zinc to a small degree. A slight precipitate was formed, but not enough to cause any trouble when a good pressure was maintained in the tank of the sprayer. The precipitate was not increased after the mixture was allowed to stand for three hours. No difference was observed in the effectiveness of the arsenical, either with or without the addition of the copper sulphate.

COPPER SULPHATE USED WITH LEAD ARSENATE.

The use of lead arsenate in combination with prickly pear without the addition of some other chemical has never been a success. A precipitate is always formed which makes it impossible to use the mixture to advantage as a spray. The same proportion of cactus and copper sulphate utilized in the zinc arsenite spray was here em-

ployed. On April 13, 1914, 1 pound of lead arsenate in the paste form was placed in 20 gallons of cactus water which contained copper sulphate in the amount of 1 pound to 28 gallons of water. It was at once noticed that the copper sulphate retarded the precipitation of the lead arsenate, so much so that the solution could be used as a spray with some success, at a normal pressure with a hand pump. This was encouraging, as it had been impossible to use lead arsenate alone in combination with cactus as an adhesive. The writer would recommend, however, that the foregoing combination be used on a large scale only when a strong pressure can be maintained throughout the operation, or the results will be unsatisfactory.

The mortality in the experiments was practically the same as when the arsenical was used alone. Had more experiments been made in the field, in all probability a higher mortality would have been observed in the end.

COPPER SULPHATE AND FERROUS ARSENATE.

The use of copper sulphate as a preservative for the cactus, combined with ferrous arsenate to form a spray, did not appear to produce any chemical changes, no noticeable precipitate being found that would prevent the use of the solution as a spray. It had been expected that more of an action would take place when the ferrous arsenate was added to the cactus water containing copper sulphate. The ferrous arsenate was not altered in insecticidal value when mixed with sulphate of copper.

EXPERIMENTS WITH OTHER PRESERVATIVES.

SALICYLIC ACID.

On March 13, 1914, 45 pounds of cactus were sliced and placed in 32 gallons of water, and in another lot 30 pounds were added to 24 gallons of water. The following day the solid portion of the cactus was removed from the two lots and the water poured from both into another receptacle. This made 56 gallons of the liquid to be preserved. One-fourth of a pound of salicylic acid was dissolved and added to the cactus water, and the mixture was allowed to stand exposed to the air. On April 1 the mixture was found to be in perfect condition. A bluish-white scum was noticed to have formed on the surface shortly after the acid was dissolved in the water. To dissolve salicylic acid a certain amount of alcohol is necessary. At first the acid was dissolved in a 10 per cent solution of alcohol, but it was later found that cactus water served equally well for this purpose after fermentation was well under way, although action was somewhat delayed.

SODIUM BENZOATE.

Sodium benzoate was used in a limited way as a preservative for the cactus solution. On March 14 one-fourth of a pound was dissolved in a small quantity of alcohol and added to a barrel containing 40 gallons of water in which 50 pounds of cactus had been placed March 13, after removing the solid portion of the pear. The mixture was stirred vigorously for five minutes and later covered. On April 2 an examination was made and the liquid used as a spray with zinc arsenite. Only slight fermentation had taken place, and no difficulty was encountered in applying the spray.

The first disadvantage in using sodium benzoate for such a purpose is its cost. It is somewhat more expensive than other chemicals of this class, and the element of cost is a primary consideration. Another feature is that it is not easily dissolved, and unless it is thoroughly dissolved its powers as a preservative are considerably lessened.

On April 2 sodium benzoate was again used in the proportion of 1 pound to 200 pounds of cactus in 100 gallons of water. This was quite a concentrated mixture, but it kept in perfect condition for two weeks, at the end of which time it was used up. The average temperature a part of the time was 80° F.

THE COMMON PRICKLY PEAR CACTI AND THEIR CHEMICAL COMPOSITION.

The common cactus or prickly pear of southern Texas is a variety known as "nopal" or "nopal azul" (*Platopuntia lindheimeri* Engelm.). This is the variety with flat, rounded leaves and growing about 4 or 5 feet high, and it is found well distributed over southern Texas. It is a native species which varies considerably in coloration of spines as well as in its general habit of growth. The fruit is purplish throughout, more so than the more spiny variety, *Platopuntia engelmannii* Salm., which is very similar in habit of growth, but usually occurs farther west than the region occupied by this species. The large spineless cactus frequently cultivated, but ordinarily not occurring abundantly in the cactus plains of southern Texas, is a species which has been called *Platopuntia tuna* Will. It grows much taller than the common "nopal" and is known in California as "mission pear" and in Texas as "Nopal de castilla." It frequently grows 10 to 15 feet in height, with the trunk 12 inches in diameter, and the joints in shape are more elliptical than rounded. The fruit is considerably larger than that of the common "nopal" and greenish throughout.

The chemical analyses of these plants, taken from Bulletin No. 60 of the New Mexico Agricultural Experiment Station,[1] are as follows:

TABLE XVII.—*Chemical analysis of Platopuntia lindheimeri.*

	Green.			Air dry.		
Sample No.	7515	7516	7567	7515	7516	7567
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Spines	0.10		0.42	0.72		2.60
Water	87.36	79.88	84.82	5.65	5.20	6.55
Ash	2.82	4.98	2.27	21.05	23.45	13.95
Crude protein	.60	.45	.96	4.49	2.12	5.92
Crude fat	.26	.20	.30	1.95	.95	1.82
Nitrogen free extract	7.54	9.55	9.84	56.26	44.98	60.61
Crude fiber	1.42	4.94	1.81	10.50	23.30	11.15
Organic matter	9.82	15.14	12.91	73.30	71.35	79.50

ANALYSIS OF THE ASH.

[Sample No. 7515.]

Carbon	per cent	0.14
Sand	do	.29
Per cent in pure ash:		
Soluble silica (SiO)		.43
Iron (Fe)		.20
Aluminum (Al)		.00
Manganese (Mg)		.49
Potassium (K)		14.22
Sodium (Na)		.35
Phosphoric acid radicle (PO_4)		1.11
Sulphuric acid radicle (SO_4)		1.15
Chlorine		2.15
Carbonic acid radicle (CO_3)		49.12

TABLE XVIII.—*Chemical analysis of Platopuntia engelmannii.*

	Green.				Air dry.			
Sample No	65621	6575	7810	78411	65621	6575	7810	78411
	P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
Spines		0.32	0.04			3.33	0.33	
Water	89.09	91.07	89.41	85.41	6.20	7.33	6.83	3.97
Ash	.91	2.00	1.60	.77	7.80	20.80	14.05	5.07
Crude protein	.48	.32	.35	.46	4.16	3.29	3.07	3.06
Crude fat	.33	.12	.23	.33	2.85	1.20	2.00	2.20
Nitrogen free extract	7.31	4.95	7.21	10.03	62.84	51.43	63.48	72.58
Crude fiber	1.88	1.54	1.20	3.00	16.15	15.95	10.57	13.12
Organic matter	10.00	6.93	8.99	13.82	86.00	71.87	79.12	90.96

TABLE XIX.—*Chemical analysis of Platopuntia tuna.*

	Green.		Air dry.	
Sample No.	7519	7577	7519	7577
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
Spines	0.36		1.82	
Water	81.86	92.25	5.18	8.12
Ash	4.29	1.75	21.65	20.80
Crude protein	1.32	.63	6.68	7.53
Crude fat	.28	.16	1.40	1.85
Nitrogen free extract	8.88	4.02	44.56	47.60
Crude fiber	4.07	1.19	20.53	14.10
Organic matter	14.55	6.00	73.17	71.08

[1] Griffiths, David, and Hare, R. F. Prickly pear and other cacti as food for stock, II. N. Mex. Agr. Expt. Sta. Bul. 60, 134 p., 7 pl., November, 1906.

SUPERIORITY OF CACTUS FROM DRY LAND.

It has been found that cactus growing near resacas and in low wet places yields less glutinous matter to the gross pound than it does when growing on high dry soil. Thus time is saved in making up a spraying solution if the cacti are collected from the higher regions, and not in or near standing water.

On April 13, 1914, 75 pounds of cactus were placed in 40 gallons of water. Twenty-four hours later the cactus was removed and allowed to drain for about one-half hour. It weighed 85.5 pounds, or $10\frac{1}{2}$ pounds more than when placed in the water. Another lot of 110 pounds was increased in weight to 124 pounds by leaving it in water 24 hours. However, when the cactus is sliced and allowed to remain in water until fermentation is well under way, there will be a slight decrease in weight. This will not happen where a preservative is used.

ADVANTAGES IN THE USE OF CACTUS AS AN ADHESIVE.

By the use of cactus as an adhesive not only do the arsenicals give better and more lasting results, but considerable expense may be saved in another way. In the Southwest, where all insecticide material must be shipped in from a great distance, the expense of transporting this material is often more than the cost of the insecticide itself, so that material of a poor quality is often used instead. For some years arsenicals in the paste form have been extensively used by fruit and truck growers on account of their better adherence and lasting qualities, but where a good adhesive is used the writer much prefers arsenicals in the powder form. In conducting experiments in the insectary and in the field at no time have the powdered arsenicals proved less effective, and at times the mortality would be considerably above that shown in another experiment conducted at the same time with arsenicals in the paste form. Better results have been obtained in using 1 pound of zinc arsenite in powder form with cactus than by the use of 3 pounds in the paste form to the same amount of water. Thus equal results may be obtained, with a reduction of 66 per cent in express and freight charges paid in securing arsenicals from a distance.

QUANTITY OF CACTUS TO USE.

The amount of cactus that may be used with good results varies with the environment under which the plants have been growing. If the plants have been growing in or near water it will be necessary to increase the quantity of cactus used to each gallon of water. In general, the correct proportion will range from $\frac{1}{3}$ pound to 1

pound to every gallon of water used in making up the spraying mixture. These proportions have given the most favorable results in all experiments conducted so far. When amounts in excess of 1 pound to each gallon of water are used the adhesive powers do not appear to be increased to any great extent, and on the other hand difficulty is experienced in applying the spray, particularly where very fine nozzles are employed.

ZINC ARSENITE AS AN INSECTICIDE.

Zinc arsenite has been used both in the paste and powder forms with much success for the belted cucumber beetle, as well as for some other insects of this class. It has proved to be one of the most effective sprays for use in humid climates, as it appears to last longer. No other arsenical has given better results, and in the majority of cases the mortality has been higher than with any other arsenical spray. The powder when used with cactus to make it adhere is to be preferred for general use over any arsenical now on the market. This spray in the writer's opinion surpasses in lasting qualities any of the arsenicals and at the same time gives a higher mortality. In action it is somewhat slower than Paris green, but it gives better results in the end. The writer would not recommend, however, that zinc arsenite be used on plants that are nearly ready for market, for the poison does not wash off easily.

FERROUS ARSENATE AS AN INSECTICIDE.

Ferrous arsenate has given very good results in combination with cactus to increase its adhesive powers. No serious effects from its use on the most delicate foliage have been observed. The cost of the product at the present time places it beyond general use as an insecticide. The ferrous arsenate in the powder form is very easily brought into suspension, requiring less time than some of the other arsenicals now more extensively used to destroy biting insects. Another feature in the use of this arsenical is that it remains in suspension exceedingly well and settles very slowly to the bottom of the tank. This makes it a most desirable poison for use with small sprayers not equipped with agitators.

IRON ARSENITE AS AN INSECTICIDE.

Iron arsenite was given a trial against the belted cucumber beetle only, and was found to give varying results. The powder was made into a spray and applied both with cactus as an adhesive and without the cactus. The iron arsenite is quite hard to bring into suspension and soon settles to the bottom of the spray tank unless constantly

agitated. Its effectiveness as an insecticide was disappointing; in fact, it is so low that it is doubtful that this arsenical can ever come into general use as a spray. Much difficulty was experienced in obtaining uniform distribution over the surfaces sprayed, even when used with cactus. The cactus increased its adherence and spraying qualities, but not sufficiently to remedy matters completely. The foregoing experiments show its effectiveness as compared with ferrous arsenate, zinc arsenite, lead arsenate, and Paris green.

FINAL RESULTS FROM SPRAYING.

The pot experiments carried on in the insectary for the belted cucumber beetle and the other species concerned were undertaken to assist in checking up results in the field. They served for more than this, however, for in a short time it was possible to accumulate much data as to the effectiveness of each spray that otherwise could not have been secured in nearly so short a time, while the estimates as to mortality in each of the experiments made would have been much less conservative.

It was found that the beetles could be best controlled by spraying with zinc arsenite or with Paris green. The other arsenicals employed, while effecting a control in most cases, did not give as high mortality as the two arsenicals mentioned. The number of applications rendered necessary varied with the location of the sugar beets, i. e., their distance from crops where the beetles were breeding in large numbers. One plat of sugar beets was sprayed only once, while on the other hand several plats of beets, spinach, and cabbage were sprayed from two to four times in order to prevent the crop from being badly stunted in growth. The greatest damage is done from the time the beets begin coming up until the leaves have reached a height of 10 inches. Attention should be given the crop from the time the seeds are planted, in order that no serious damage may be done before remedial measures can be put to practice.

RECOMMENDATIONS FOR CONTROL.

The control of such pests as the belted cucumber beetle does not require the attention necessitated by some of the noxious caterpillars and sucking insects. But to keep the injury down to the minimum frequent observation should be made while the plants are small, as this is the time when the beetles are capable of doing the greatest amount of damage.

If the beetles are present in sufficient numbers partially to defoliate a few plants, it is time to begin spraying. It may be necessary to spray only once in order to effect control, but this will depend upon the surrounding vegetation as well as upon the weather conditions.

Any of the arsenicals may be used in the form of a spray to control this beetle. If arsenite of zinc in paste form is to be used, the writer will recommend 3 pounds to 50 gallons of water, in combination where possible with some adhesive, in order that best results may be obtained. In the Southwest the prickly pear serves the purpose best, because better results have been obtained where it was used than with any one of several other adhesives. From an economic standpoint, also, it has first rank as an adhesive and spreader. It has been ascertained that zinc arsenite in the powder form in the proportion of 1 pound to 50 gallons of water in combination with cactus gives a little higher mortality than 3 pounds in the paste form, and a more extensive use of this powdered form is to be recommended, particularly in the cactus-growing region or where the glutinous matter of this plant can be had for use in the spray.

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BULLETIN OF THE U.S. DEPARTMENT OF AGRICULTURE

No. 161

Contribution from the Bureau of Entomology, L. O. Howard, Chief.
December 18, 1914.

THE MEDITERRANEAN FRUIT FLY IN BERMUDA.

By E. A. Back,

Entomological Assistant, Mediterranean Fruit-Fly Investigations.

INTRODUCTION.

This paper is the result of an investigation of the fruit-fly situation in Bermuda, made by the writer during December, 1913, at the request of Mr. C. L. Marlatt, Assistant Chief of the Bureau of Entomology and chairman of the Federal Horticultural Board, in order to gain at first hand information that might be of value to the Horticultural Board in framing its quarantine regulations against this pest.

HISTORY OF THE FRUIT FLY IN BERMUDA.

The Mediterranean fruit fly, *Ceratitis capitata* Wied., was not recorded in literature from Bermuda until 1890, when Riley and Howard [1] report receiving specimens of infested peaches from St. George. However, it had been known as a pest in Bermuda many years before this date, as Mr. Claude W. McCallan, who forwarded these specimens to Washington, stated in his accompanying letter of April of that year that peaches had been subjected to its ravages during the 25 years previous. About the year 1865 a vessel carrying a cargo of fruit from the Mediterranean regions, bound for New York, was forced by severe storms to discharge her cargo in Bermuda, and it is the general belief that at that time the pest gained its foothold in this English possession. But whatever the source of infestation, it is a well-known fact that for nearly 50 years the peach industry of these islands has been a ruined one, and that at the present time the fruit fly is generally distributed over the islands ready to infest all host fruits coming to maturity.

LIFE HISTORY.

Those wishing a detailed description and life history of the Mediterranean fruit fly should refer to the publication of Quaintance,[2] published by the Department of Agriculture.

[1] Riley, C. V., and Howard, L. O. The peach pest in Bermuda. (*Ceratitis capitata* Wied.) Order Diptera: Family Trypetidæ. In U. S. Dept. Agr., Div. Ent., Insect life, v. 3, no. 1, p. 5–8, 2 figs., August, 1890.

[2] Quaintance, A. L. The Mediterranean fruit fly. U. S. Dept. Agr., Bur. Ent. Circ. no. 160, 25 p., 1 fig., Oct. 5, 1912.

NOTE.—This bulletin discusses the history of the fruit fly in Bermuda, the life history of the insect, and the possibility of eradicating it from Bermuda; the bulletin is of interest to entomologists.

EGG, LARVA, AND PUPA.

Col. W. R. Winter, in his bulletin entitled "The Fruit Fly," published by the Bermuda Department of Agriculture in 1913,[1] gives the only data secured in Bermuda on this pest up to that date. He states that he has found that to pass through the egg, larval, and pupal stages the fly requires from 17 days, during the heat of August, when the monthly mean temperature averages about 81° F., to 6 weeks in winter, when the mean temperature averages about 63.2° F.

With the assistance of Mr. E. J. Wortley, Director of Agriculture of the Bermuda Department of Agriculture, the writer found that the pupal stage alone in Bermuda, when the daily mean temperatures ranged between 62.5° and about 64.8° F., might be lengthened to about 31 days under normal conditions.

Back and Pemberton have found that a temperature varying from 58° to 62° F. increases pupal life to from 29 to 31 days. They have likewise found that while eggs hatch in from 2 to 3 days in Hawaii at a mean temperature of about 79° F., hatching may be delayed until 6 days after deposition when the mean temperature drops to about 71° F., or until 7 to 14 days when the temperature ranges from 54° to 57° F. It has also been found in Hawaii that while the larval stage may require a minimum of 5 to 6 days at a mean temperature averaging about 79° F., it requires from 36 to 53 days in apples at temperatures ranging from 56° to 57° F.

These data are given to substantiate the belief of the writer that the duration of life from the egg to the adult in Bermuda where the winter mean averages about 63° F. is somewhat over two months, and may even be three months under unfavorable circumstances.

THE ADULT.

In the Hawaiian Islands, where the summers are somewhat cooler and the winters slightly warmer than in Bermuda, adult flies have been kept alive over five months. While the majority do not live this long, the belief has been expressed that a few flies may live to be over six months of age, especially during such cool weather as obtains in Bermuda during the winter. Both sexes are sexually immature when they emerge from the pupa. At temperatures varying from 76° to 78° F., the sexes mate when 5 to 8 days old, though not until 2 weeks old at 61° to 64° F. One prolific female deposited on an average of about 4.5 eggs per day during the first 18 weeks of her life, and had not then reached her egg-laying capacity. As many as 25 eggs have been laid by a single female in one day. Female flies do not lay a large number of eggs at one time and then die, as many believe, but lay quite regularly a few eggs nearly every day throughout life.

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[1] Winter, W. R. The fruit fly. Bermuda, 1913. 14 p. (Bermuda Dept. Agr., E. J. Wortley, director.)

HOST FRUITS IN BERMUDA.

Col. W. R. Winter, in the bulletin previously mentioned, lists 47 fruits subject to attack. To this list for Bermuda should be added the ball kamani (*Calophyllum inophyllum*), the prickly pear (*Opuntia* sp.), and the acordia. While the list of host fruits given is so large that one receives the impression that the fruit fly has an abundance of fruit in which to develop, conditions are quite the opposite in Bermuda. After having carried on a clean-culture campaign against this pest in the Hawaiian Islands, where there exists a very great abundance of many host fruits, the writer was surprised at the scarcity of host fruits in Bermuda. In Table I is recorded the vegetation found growing in portions of the city of Hamilton.

TABLE I.—*Vegetation in Hamilton, Bermuda, with reference to host fruits for the Mediterranean fruit fly.*[1]

Kind of tree.	Number of different trees on various properties.[2]													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Apple													1	
Acalepha	1	1	1		1	1	1	1	1		1	10	6	7
Anona								1			1		2	1
Aracaria			1										3	
Avocado		1							1		1	2	6	11
Banana				1			1	1	1	1	1	75	24	65
Cedars	1	1	1			1	1	1	1	1		2	23	1
Chinaberry	1				1		1	1	1			2	8	15
Citrus									1					
Coffee					1									
Crape myrtle					1		1			1			3	1
Croton							1		1		1	10	6	4
Eugenia	1	1					1			1			2	
Fiddlewood		1							1			3	9	
Guava														
Hibiscus	1	1	1	1	1	1			1			12	6	4
Kamani, ball					1							1		1
Kamani, winged												1		
Loquats		1		1				1	1		1	12	22	10
Mango				1										1
Mulberry				1										1
Oleander		1	1			1	1	1	1			2	8	3
Pandanus	1		1		1							1		
Papaya			1	1			1	1	1	1		3	12	27
Peach								1					10	
Pigeonberry							1	1				2	2	4
Poinciana				1	1								1	1
Roses														
Rubber tree	1		1				1						1	1
Sapodilla					1			1				1		
Thevetia					1									

[1] All trees and shrubs were recorded except the following nonhost plants: Bamboo 5, buttonwood 5, Dracaena 3, elder 1, Lantana 3, Mimosa 2, pomegranate 1, privet 2, Australian pine 2, tamarind 1, sea grape 2, coconut palm 1, palmetto 8, date palm 8, sago palm 3, Poinsetta 2, Euphorbia 7, Althea 1. Host plants of the Mediterranean fruit fly are in italics.

[2] Nos 1 to 11 represent private premises; Nos. 12 to 14, city blocks.

The number of trees and shrubs in Bermuda which bear fruit subject to attack is very small. Out of 9,828 acres of land only 2,636 acres were recorded under cultivation in 1901, and this acreage has but slightly increased. The principal products raised for export, potatoes, onions, arrowroot, lily bulbs, and garden vegetables, except peppers, are not subject to attack. On the uncultivated areas the host fruits are mainly conspicuous by their absence. In such areas

the escaped Surinam cherry (*Eugenia micheli*) and a small species of prickly pear (Opuntia) are to be found in varying numbers. In the Tuckerstown district the former is quite abundant, while the latter is plentiful in sandy locations, as noted especially in Southampton Parish along the south shore. The soil of Bermuda, being very shallow, does not support dense vegetation. Cedar trees are so generally distributed over the islands that the landscape, as viewed from a tower, appears blackened by them. One can often walk among them long distances, as distances go in Bermuda, without seeing a single tree bearing fruit subject to attack. Often the cedar, fiddlewood (*Citharexylum quadrangulare*), the oleander (*Nerium oleander*), the Lantana (*Lantana odorata* and *L. crocea*), the life plant (*Bryophyllum calycinum*), grasses, and a few weeds are all that one sees. Some of the small islands of the group were found to support nothing subject to attack. In and about Tuckerstown and the adjoining limestone region the vegetation is more dense, and progress through the woods is made difficult by the presence of rocks and vines. In this region are to be found many neglected bittersweet oranges, whose fruits, according to Col. W. R. Winter, are quite eagerly gathered for marmalade, although often the trees are difficult of access.

It was found that the principal fruits supporting the fruit fly in Bermuda were:

(1) The loquat or Malta plum (*Eriobotrya japonica*), which ripens during January, February, and March.

(2) Peaches, which ripen during late March, April, May, June, and early July.

(3) Surinam cherries (*Eugenia micheli*), the first crop of which ripens during May and the second crop throughout summer and early fall.

Director of Agriculture Wortley informed the writer that the cultivated bell pepper was also a source of food for the fruit fly during the summer months.

AMOUNT OF FRUIT.

No large amount of fruit subject to infestation by the fruit fly is to be had in Bermuda at any season of the year unless it be during the time when Surinam cherries are in season. It would not be just to Bermuda horticulturists for one visiting these charming islands for so short a time during the winter to state that many of the more tropical fruit trees appeared stunted and grown only with great care in favored gardens; yet it so seemed to the writer. It would be very easy to count the number of apple, guava, mango, and bestill trees (Thevetia) in the islands. One common guava was pointed out in a beautiful garden as a curiosity. Only one winged kamani, one sweet almond (Terminalia) and one apple tree were seen. The avocado, citrus, papaya, and peach trees were more numerous, though by no

means plentiful. The loquat seemed to be the most abundant cultivated fruit, but few of the trees were as large or as well developed as those in Florida or Hawaii, and their ripening fruit was, at the time of the writer's visit, everywhere generally infested. Experimenters wishing to rear flies in large numbers for scientific purposes would be forced, in the opinion of the writer, to depend upon imported fruits, such as apples, in order to have a constant and satisfactory supply.

POSSIBILITY OF ERADICATION.

From the experience of the writer with clean cultural methods covering nearly two years in the city of Honolulu, Hawaiian Islands, he believes that the Mediterranean fruit fly can be eradicated from Bermuda within three years at the longest without the expenditure of a prohibitive amount of money. If the fruit flies were not capable of living so long in the adult stage, it is probable that the work of eradication could be accomplished in less time. There is probably no country in the world where the fruit fly exists in which the work of eradication could be undertaken with such assurance of success, provided the work were placed in the hands of a persistent, well-informed, intelligent person who could carry on an uninterrupted campaign authorized by adequate legislation. The fruits infested at the present time are such that no citizen would be forced to bear any real financial loss as the result of such a campaign. The peach and loquat fruits are practically all destroyed yearly by the fly, and the Surinam cherries are of no commercial value. By the judicious use of axe and saw and by thorough cutting of flowers or young fruit on those few trees that can not for various reasons be either cut down or prevented temporarily from bearing by severe pruning, the host fruits could be eliminated. It has already been shown that oranges and grapefruit act more as traps for the fruit fly than as hosts if allowed to remain on the tree until sufficiently ripe for table purposes, and such trees of value need not be destroyed provided the fruit be gathered before it becomes overripe.

The Bermuda agricultural authorities had already secured the passage of legislation against this pest and started clean cultural work as early as March, 1907, when the board of agriculture, as stated by Col. Winter in a letter to the writer under date of February 20, 1914, was given the power to "prohibit the growing of any fruit or vegetable, to clear off fruit, cut back or destroy as necessary any trees or vegetables, and to clean up the ground beneath them." The inspection work was already yielding good results when the fruit fly destruction act of 1907, under which it was being carried on, lapsed on December 31, 1910. No work was done during 1911 and 1912, although a new act was passed in June of the latter year. During 1913 inspections were again started, but apparently had accom-

plished little in controlling the fruit fly, as evidenced by the general infestation noted by the writer in ripe loquats and Thevetia in December of that year.

In other words, the money appropriated in Bermuda for inspection work against the fruit fly has not yielded practical results. The small amount of fruit grown in the islands does not warrant the expenditure of money except with the object of extermination in view. It is only by extermination that fruit growers in Bermuda can hope to produce those fruits which her climate makes possible without maintaining a system of inspection that at best will yield but temporary results and at the same time be a source of perpetual expense amounting to more than the fruits now grown are worth. The work carried on by the Federal Government in Hawaii has clearly demonstrated the fact that no clean cultural method will lead to any lasting beneficial result unless the person in charge of such work be given the power, either personally or through able inspectors, to plan the destruction of all fruit before it begins to ripen, either by the destruction or severe pruning of host trees or the gathering of fruit before it is sufficiently developed to become infested. Just so long as notices are served on residents demanding them to destroy fruits on their properties already known to the inspector to be infested with the fruit fly, just so long will failure attend clean-culture work. The director of a clean-culture campaign must have full power to destroy fruit whenever he knows that the facts demand it. Human nature is the same the world over. Lack of interest on the part of a few citizens when the destruction of fruit is left in their hands can defeat and has defeated the plans of the most able directors. These statements regarding clean-culture work are based upon the results following the expenditure of many thousand dollars in similar work in the Hawaiian Islands and elsewhere.

BERMUDA AS A SOURCE OF DANGER TO THE UNITED STATES.

If Bermuda were in direct communication with the southern Atlantic ports of the United States, to which she is so closely situated, she would be a source of great danger to the fruit interests of the Southern States. However, her only regular and direct communication is by means of vessels plying between Hamilton and New York, a distance of about 701 miles, for the passage of which about two days is required. Another line of steamers, equipped with limited passenger accommodations and running about every four weeks, connects London and Hamilton. The vessels of this last company usually continue on to Cuban ports, and thence to a southern port of the United States for freight before returning to England. Such small quantities of fruit are brought to maturity in an edible condition in Bermuda that there is very slight probability of any

being carried to the United States. Native-grown fruit is scarce and a luxury even for the few who are able to grow it. Practically all the fruit consumed in Bermuda and on the ships plying between Hamilton and New York is grown in the United States. Furthermore, the climatic conditions in and about New York are known to be decidedly against the establishment of the fruit fly, even if it should be accidentally introduced. The fact that ships have been plying between New York and Bermuda for many years without the pest having become established on the mainland is an argument in itself. Practically all agricultural produce grown in Bermuda can not be marketed profitably in New York, where it is for the most part consumed, unless it is placed on the market before that grown in the Southern States is shipped north. Thus the bulk of Bermuda-grown vegetables, whether subject to infestation or not, arrives in New York at a season when the climate is too cold for the pest to survive. With the addition at the present time of the strict quarantine regulations against all Bermuda-grown fruits or vegetables subject to attack, to the restrictions already placed by nature and the market, it would appear that Bermuda is a source of very little danger to the United States from the fruit-fly standpoint.

CONCLUSION.

The Mediterranean fruit fly, *Ceratitis capitata* Wied., was introduced into the Bermuda Islands probably about 1865, when fruit supposedly infested by this pest was unloaded there from a storm-tossed vessel from the Mediterranean region. Since that time the fruit fly has spread over the entire 19½ square miles of rolling country of which these islands are composed, and long since has ruined the excellent peach industry enjoyed by Bermuda in the early days and has caused such discouragement among prospective fruit growers that at the present time native-grown fruit in Bermuda is a luxury.

While Bermuda is probably at present a source of comparatively small danger to the United States as a source of infestation by the Mediterranean fruit fly, both on account of her trade relations and the climatic conditions surrounding New York, the extermination of the pest in these islands will be decidedly to the advantage of both Bermuda and the United States. All parts of Bermuda are easy of access. The topography is cut up by harbors, lakes, and roads into small areas that can be easily inspected; the trees and shrubs, the fruits of which are subject to infestation, are surprisingly few numerically, and a large portion of the uncultivated lands supports little that is subject to attack.

Experience in all countries where clean cultural work has been undertaken, but especially in the city of Honolulu, has shown that

no lasting beneficial results will follow such work as has been carried on in Bermuda unless extermination is the object in view. The value of the fruit grown in Bermuda is not sufficient to warrant work being carried on with any other object. In no country where the fly now exists could work of extermination be undertaken with such assurances of success as in Bermuda. If clean cultural work were supported continuously by adequate legislation and undertaken by a person sufficiently conversant with the problem and eager to make a unique record in the entomological world, the Mediterranean fruit fly could be exterminated from Bermuda within three years, without the expenditure of a prohibitive amount of money.

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BULLETIN OF THE
U.S. DEPARTMENT OF AGRICULTURE

No. 162

Contribution from the Bureau of Plant Industry, Wm. A. Taylor, Chief.
January 13, 1915.

HORTICULTURAL EXPERIMENTS AT THE SAN ANTONIO FIELD STATION, SOUTHERN TEXAS.

By STEPHEN H. HASTINGS, *Farm Superintendent*, and R. E. BLAIR, *Scientific Assistant, Office of Western Irrigation Agriculture.*

INTRODUCTION.

Comparatively little authentic information is accessible regarding the possibilities of fruit culture in the vicinity of San Antonio. Small orchards are found on a few farms here and there, but most of the farmers have little fruit, even for home consumption, and there are no commercial orchards of consequence in the region. Many farmers have planted orchards, but they have become discouraged because of unsatisfactory results, due largely to the selection of varieties not suited to the conditions or to neglect of the trees after planting.

It is not to be expected that commercial orcharding will ever become an important feature of the agriculture of the San Antonio region, but there is no apparent reason why every farmer should not have at least a small orchard to furnish fruit for home consumption. It will be seen from the following pages that the list from which the farmer may select is relatively large.

The greater part of the fruit consumed in the city of San Antonio is shipped in from outside districts. While it is to be expected that the local market will continue to depend upon outside sources, many fruits, such as peaches, grapes, plums, berries, and persimmons, can be produced locally to good advantage and will find ready local sale.

There are a number of factors which have operated to hinder the production of fruit in this section. The climate is characterized by wide extremes of temperature and precipitation, and many failures can be traced directly to climatic causes. The soil is not favorable to the successful growth of some kinds of fruit trees, chiefly because of the excess of lime which it contains, and there are many plant diseases which cause much trouble and damage.[1]

[1] For detailed information regarding the plant diseases of this region, see Heald, F. D., and Wolf, F. A., A plant-disease survey in the vicinity of San Antonio, Texas, U. S. Dept. Agr., Bureau of Plant Industry Bul. 226, 129 p., 19 pl., 1912.

NOTE.—This bulletin indicates the selections and cultural methods best adapted to successful fruit growing in the vicinity of San Antonio and is of interest to the inhabitants of that region.

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Most fruits mentioned in this paper have been growing under observation for eight years. While this period is too short to permit definite conclusions in every case, it has seemed best to publish the information so far obtained, in order to meet the numerous inquiries received concerning this phase of the work of the San Antonio Field Station.

CLIMATIC CONDITIONS OF THE REGION.

While the winters of San Antonio are mild, the occasional low temperatures prevent the growing of many of the more tender fruits. The severity of the winter climate is not due wholly to the low temperatures, but in a large measure to the suddenness of the changes, which often cause an extremely wide range of temperature in a few hours. Many of the northers which bring the temperature down to a few degrees below freezing are preceded by periods of warm, summerlike weather that start the plants into growth and put them in the worst possible condition to withstand the cold. The minimum temperature does not ordinarily go much below 15° F., as is shown in Table I.

TABLE I.—*Absolute minimum temperatures at San Antonio, Tex., 1892 to 1913, inclusive.*[1]

Year.	Temperature.	Year.	Temperature.	Year.	Temperature.
	°F.		°F.		°F.
1892	19	1900	19	1908	18
1893	26	1901	15	1909	17
1894	16	1902	26	1910	12
1895	11	1903	19	1911	13
1896	27	1904	22	1912	16
1897	18	1905	13	1913	20
1898	20	1906	24		
1899	4	1907	27	Mean minimum.	18

[1] The temperatures for the years 1892 to 1906, inclusive, are taken from the records of the U. S. Weather Bureau, and those for the years 1907 to 1913, inclusive, from the records of the San Antonio Experiment Farm.

The annual rainfall at San Antonio has averaged about 26 inches for the past 20 years. (Fig. 1.) This, if well distributed, should be ample for most fruit trees, and in ordinary seasons should mature a fruit crop, particularly if the trees are planted somewhat farther apart than is now customary and the orchards given good care and culture. In fact, the writers are convinced that the rainfall is not the chief limiting factor in growing such fruits as peaches and plums where the orchard receives proper care, although it must be expected that seasons will occur when the fruit crop will suffer because of insufficient rainfall.

Table II gives the rainfall at the experiment farm for the years 1907 to 1913, inclusive. A comparison of these figures with the

records kept by the Weather Bureau at San Antonio for a much longer period will show that the mean rainfall for the last seven years is slightly below what is to be ordinarily expected. The year 1909, which was the driest that has been known during the observed period (more than 40 years), was followed by two years when the rainfall was considerably below normal. In spite of the adverse conditions during this period, the orchards came through with no loss of trees which could be traced directly to a lack of moisture.

TABLE II.—*Annual precipitation at the San Antonio Experiment Farm, 1907 to 1913, inclusive.*

Year.	Precipitation.	Year.	Precipitation.	Year.	Precipitation.
	Inches.		*Inches.*		*Inches.*
1907	26.68	1910	20.02	1913	36.71
1908	26.27	1911	23.93		
1909	13.14	1912	26.37	Mean	24.66

THE SOIL CONDITIONS.

San Antonio lies in the southern extension of what is known as the Black Prairie region, or the "Black Lands" of Texas, and near the northern edge of an area known geographically as the Rio Grande Plain. The soil is mostly the result of the weathering of limestone rocks of the Upper Cretaceous period. Recent alluvial deposits have been washed down from the higher lands northwest of the city, resulting in modifications through the addition of coarser material. The typical soil is a heavy black or brownish loam.

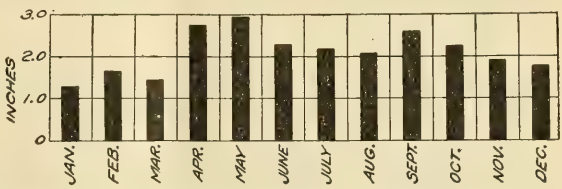

FIG. 1.—The mean monthly rainfall at San Antonio, Tex., from 1891 to 1913. (Compiled from the records of the United States Weather Bureau.)

The lime content of the soil is unusually high, the proportion of carbonate of lime in the upper 12 inches ranging from 7 to 23 per cent. This lime occurs in the soil both as a finely divided material and as gravelly concretions. In the former condition it is generally dark colored through staining by decomposed organic matter, while in the latter condition it is usually white

This excess of lime is believed to be the cause of one of the most serious disorders of fruit trees that have been encountered in the experimental work reported in this paper. The chief symptom is a yellowing of the leaves, and in the later stages the leaves drop and the tree gradually dies. Often in less severe cases the tree may continue to live and make a poor growth and bear some fruit for several years

before it finally succumbs. This disorder or disease is known locally as chlorosis.

Another serious disease which has caused much trouble is root-rot. This disease is believed to be due to a fungus (a species of Ozonium) which lives in the soil and is often more destructive than chlorosis. Some species are particularly susceptible to root-rot, though certain individuals may escape it for some years, probably because of lack of infection.

Crown-gall[1] is a disease that occurs frequently in the San Antonio soils, and there are a large number of species of soil-inhabiting nematodes which are parasitic on the roots of cultivated trees and shrubs.

It is not clear in every case just what causes the disease or death of the plants. It is probable that in many instances there are several causes working together. These causes are, however, located in the soil and separately or together constitute a serious problem, both to fruit production and to experimental work with fruit trees.

SCOPE OF THE EXPERIMENTS.

The horticultural work of this field station has been directed along two major lines: (1) To find which varieties are best adapted to the local conditions and (2) to find what varieties or species can be used as stocks that will be relatively immune to soil troubles and will permit the use of desirable but susceptible varieties as scions. In addition, some work has been started in the way of making hybrids between the native species and related domesticated varieties.

When this work was begun in 1906 and 1907, a collection of varieties was assembled, chiefly from commercial nurseries. This collection has been added to from time to time, and the Office of Foreign Seed and Plant Introduction has placed at the station many new varieties of fruits. In all the tests of varieties, at least two individuals of each kind have been used in the experiment. Sufficient information has been acquired in the tests here reported to prove that a reasonably large list of fruits can be produced by every farmer with which to supply at least his own needs. A number of peach varieties, which ripen from the middle of June to September, have proved adapted to the section. Plums, the most satisfactory fruit of this region, quality and reliability considered, furnish a large list of varieties from which to select, although their ripening season is comparatively short. A fairly large number of varieties of grapes can be grown successfully, although for table use their quality is low. Pears have been grown in the vicinity for a long period and the results observed from the better managed orchards in favored situations indicate that certain

[1] This disease and its causal organism are described in detail in Bureau of Plant Industry Bulletin 213, entitled "Crown-Gall of Plants; Its Cause and Remedy," by Erwin F. Smith, Nellie A. Brown, and C. O. Townsend, issued Feb. 28, 1911.

varieties of pears could be used in the farmer's orchard with the expectation of securing reasonably good results. Persimmons, when worked on resistant stocks, do well and produce fruit nearly every year. Pecans are native here, and while they probably can not be grown successfully on the uplands without an outlay for irrigation that would be prohibitive, they can be grown on the low lands, where there is ground water within reach of the roots. Dewberries should be included in the farmer's garden and by selecting several of the better varieties should prove a valuable addition to the fruit supply for his table.

Owing to the demand made upon the experiment farm for all the information available regarding the possibilities of fruit culture in this section, it has seemed best to include the information available regarding many other fruits which have been tested, but not sufficiently to ascertain how large a part they will play in the fruit production of the region.

In some instances, for example apples and cherries, there is no information at hand that would indicate that they should be added to the farmer's orchards; in fact, the weight of evidence is against them. In the case of other and less common fruits, such as the citrange, there is a lack of information regarding how they will behave under local conditions.

VARIETY TESTS.

PEACH SELECTIONS.

The experimental work with peaches has shown some of the reasons why this crop has not been generally successful in the San Antonio region. Notwithstanding the fact that the trees often grow well, particularly when young, it appears that the standard varieties of the North seldom fruit in this region and are slow to develop flowering buds. They also show other irregularities, such as blossoming in the autumn and early winter, or the blossoms may be delayed until very late in the spring. This lack of adaptability is such as to disqualify many varieties and limit the selection to sorts that do not show these tendencies. With a few exceptions, the varieties of the Persian, North China, and Peen-to races have shown this undesirable new-place effect or for one reason or another have not been productive. On the other hand, varieties of the Spanish and South China races, and especially some of the better seedlings from these varieties, have been found much better adapted to San Antonio conditions. Not all of the varieties of these last two races are satisfactory, however, particularly some of those of the Spanish group. A few of them, particularly of the South China race, are highly susceptible to chlorosis, and some varieties of both races have proved to be shy bearers or to yield inferior or mediocre fruit.

There still remains much to be done in testing these adapted varieties on different stocks. The few experiments made so far indicate that this is a very promising direction for experimentation.

It seems certain that some of the seedlings selected from among the Spanish or Mexican sorts will prove more immune to chlorosis and generally better adapted to the conditions than the seedling stock ordinarily used by nurserymen. The newly introduced Chinese wild peach (*Amygdalus davidiana*) also gives promise of a high degree of immunity to the local soil difficulties. It remains to be shown just

FIG. 2.—A tree of the Honey peach, one of the most reliable for the San Antonio section. This tree is located in the variety-testing orchard in field A-1. Although the trees in this orchard are planted closer together than is desirable for commercial plantings and the orchard has never been irrigated, the trees have made a good growth and some of the varieties have fruited abundantly. (Photographed June 25, 1912.)

how much can be gained by working some of the more desirable but susceptible varieties on these resistant stocks.

In the variety test here reported no special stocks have been used. The trees in the test were purchased from commercial nurseries in Texas and the northern part of Florida and were presumably budded upon the seedling stocks in ordinary use in those nurseries.

In this test the trees of 30 varieties were set in January, 1906, and 5 varieties were set in March of the following year. Two trees of each variety were planted and the orchard has been given thorough, clean cultivation, except for the plowing under of a winter crop of Canada

field peas in the spring of 1912, and again in the spring of 1913. The orchard has never been irrigated, and, although the trees are only 15 feet apart, they have not suffered severely from drought (fig. 2). This test orchard is located in field A–1.[1]

In Table III is given a list of the varieties included in the test, with an indication as to the race to which each variety belongs, where this fact is known. It has seemed best to group them thus, even when it is appreciated that there is a variance of opinion as to where a few of the varieties belong. In the case of crosses it is not always clear in which group to place the variety, and in such instances the predominating race is indicated. Opposite each variety name is given the number of years of fruiting, and the last column indicates the size of the crops. It was found impracticable to give the average yield in pounds, for frequently only a few trees fruited and the injury to the fruit by birds before gathering so reduced the yields that the figures would be of little value and in some instances misleading.

TABLE III.—*Varieties of peaches tested, showing the class to which each belongs, the number of years fruited, and the character of the crop, San Antonio Experiment Farm, 1906 to 1913, inclusive.*

Variety.	Race.	Fruited.		Variety.	Race.	Fruited.	
		Years.	Size of crop.			Years.	Size of crop.
Angel	Peen-to	2	Fair.	Jewell	Peen-to		
Late Bidwell	do			Japanese Dwarf		2	Poor.
Early Bidwell	do			La Reine	Spanish	1	Good.
Chilow	North China			Maggie	Peen-to		
Climax	South China	5	Good.	Oviedo	South China	2	Do.
Cabler	Spanish	2	Fair.	Pallas	do	5	Do.
Countess	Spanish×Persian.	1	Poor.	Peen-to	Peen-to		
Colon	South China	3	Fair to good.	Powers	Spanish	1	Fair.
Dorothy	Peen-to			Reeves Orange	do		
Estella	Spanish	2	Poor.	Ceylon			
Everbearing	do	2	Do.	Rivers	Persian	1	Do.
Florida Gem	South China	4	Good.	Suber	Peen-to	1	Poor.
Florida Crawford	Spanish			Taber	South China	4	Fair to good.
Gibbon	do			Triana	do	4	Good.
Hall Yellow	Peen-to	1	Fair.	Onderdonk	Spanish	1	Poor.
Honey	South China	4	Good.	Victor	North China × Spanish.		
Imperial	do	5	Do.	Waldo	South China		
Indian Cling	Spanish (?)	1	Poor.				

Table III shows that the varieties of the South China races have so far given the best results. The Pallas, Honey, Imperial, Climax, Florida Gem, and Triana varieties, all belonging to the South China race, are rated as the best, and their performance has been in the order in which they are here named. These results should not be taken as final. Further investigations may develop other and more valuable varieties, and, as already stated, it may be found that the use of other

[1] For a map of the San Antonio Field Station, showing the location of this orchard, see Bureau of Plant Industry Circular 34, "The Work of the San Antonio Experiment Farm in 1908," by F. B. Headley and S. H. Hastings, issued July 22, 1909.

stocks may make it possible to adopt more desirable varieties than those named. All of these South China peaches are small, delicate, and thin skinned, and consequently their use is limited to home consumption or to local markets.

Aside from these definite limitations as to varieties, the production of peaches in the San Antonio region is subject to much the same vicissitudes of climate as in any other peach-producing section. Yet with good cultivation and particularly if the trees are planted well apart, the use of a green-manure crop occasionally appears to be all that is needed to maintain the fertility of the soil, and the various insect pests and fungous diseases of the branches, leaves, and fruits are subject to control by proper spraying.

The net result of this test of peach varieties is to demonstrate the entire practicability of producing on every farm an abundant supply of fruit of excellent quality for home and local consumption. As is shown later (Table IV), these varieties ripen during a fairly long period, beginning in the latter part of June and extending through July and August. Furthermore, if it is desired, the peach season may be materially lengthened by the use of other varieties, which, though possibly somewhat less certain or less prolific, are still worth planting.

SEEDLING PEACHES FROM MEXICO.

In addition to the collection of named varieties already discussed, a seedling orchard,[1] originally of about 500 peach trees, has been grown and fruited with a view to the selection of varieties particularly adapted to local conditions. (Fig. 3.) It was also hoped that this orchard might yield seedlings better suited as stocks for budding with named varieties than the stocks generally used by nurserymen.

These seedlings have shown great diversity as regards vigor, adaptability to local conditions, productiveness, time of ripening, and quality of fruit. After having been fruited for four years, this orchard shows at least 10 trees worthy of description, propagation, and further study. The following trees, with descriptions, all but one of which have been given Seed and Plant Introduction numbers, are undoubtedly the best:

(1) Distributed under S. P. I. No. 32372, classification, South China; fruit, medium size, elliptical, unequal; cavity, large, regular, deep, with abrupt slope; suture, long and deep; apex, long, crooked, pointed, and fleshy; color, pale green, blushed with red; skin, medium thin and tender; flavor, sweet; quality, very good; freestone; ripens the latter part of June; tree vigorous and a good bearer.

[1] The seed from which these trees were produced was collected in Mexico by Mr. Gilbert Onderdonk under the direction of the Office of Foreign Seed and Plant Introduction. They are listed under S. P. I. Nos. 9320 and 9321. For the early history of this orchard see Bureau of Plant Industry Circular 34, entitled "The Work of the San Antonio Experiment Farm in 1908," by F. B. Headley and S. H. Hastings, issued July 22, 1909.

(2) Distributed under S. P. I. No. 32373; classification, South China; fruit, medium size, ovate, and unequal; cavity, medium size, deep, narrow, and abrupt; suture, long and very deep; apex, long, fleshy, and pointed; color, pale green, blushed with red; down, light; skin, thick and tough; flesh, pear white, red at seed, firm, fine, and juicy; flavor, very sweet and very good; freestone; ripens between the middle and the last of August; tree vigorous and a good bearer.

(3) Distributed under S. P. I. No. 32374; classification, Spanish; fruit, medium size, ovate; cavity, large, deep, broad, and slope gradual; suture, deep, very deep at cavity; apex, long and pointed; color, bright greenish yellow; down, medium; skin, thick and tough; flesh, orange yellow, juicy, and firm; flavor, mild, subacid, and very good; cling; ripens between the middle and the last of August; tree very vigorous and a heavy bearer.

(4) Distributed under S. P. I. 32375; classification, Spanish; fruit, round to oblate, but pointed and medium size; cavity, large, broad, deep, and flaring; suture, shallow, but deep at cavity; apex, long, fleshy, and pointed; color, pale whitish yellow; down, light; skin, medium thick and tough; flesh, pale greenish white, medium fine, firm,

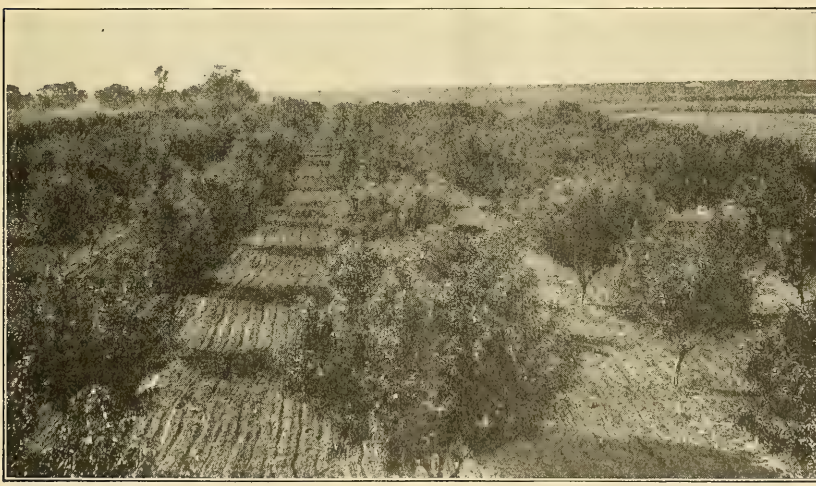

FIG. 3.—The Mexican seedling peach orchard. This orchard of originally 265 trees has produced a few trees that may prove to be of value. (Photographed in the spring of 1910.)

and juicy, subacid, good to very good; cling; ripens about the middle of August; tree very vigorous and a medium heavy bearer.

(5) Distributed under S. P. I. No. 32376; classification, South China × Spanish; fruit, medium size; cavity, large, broad, deep, and slope gradual; suture, medium, very deep at cavity; apex, long and pointed; color, greenish white; down, heavy; skin, thick and tough; flesh, greenish white, tender, medium juicy, subacid, and quality good; freestone; ripens from the first to the middle of August; tree fairly vigorous and a medium heavy bearer.

(6) Distributed under S. P. I. No. 32377; classification, Spanish; fruit, medium to large, round, and pointed; cavity, large, broad, deep, and flaring; suture, deep, very deep at cavity; apex, short and pointed; color, greenish white; down, heavy; skin, medium thick and tough; flesh, pale greenish white, slightly tinted, pink at apex of seed, firm, juicy, mild, subacid, and quality good; cling; ripens early in September; tree vigorous and a heavy bearer.

(7) Distributed under S. P. I. No. 32378; classification, Spanish; fruit, ovate, medium to large; cavity, large, very broad, deep, and flaring; suture, medium deep;

apex, short and pointed; color, greenish yellow; down, medium; skin, thick and tough; flesh, deep yellow, firm, medium tender, juicy, subacid, and medium to good quality; cling; ripens early in September; tree medium vigorous and a medium bearer.

(8) Distributed under S. P. I. No. 32379; classification, South China; fruit, elliptical, unequal, medium size to small; suture, medium deep; apex, long, fleshy, and pointed; color, pale green, tinted with red; down, medium; flesh, greenish white, tender and juicy, mild, subacid to sweet, and quality good; freestone; ripens from the middle to the last of July; tree vigorous and a good bearer.

(9) Distributed under S. P. I. No. 32380; classification, South China; fruit, medium small; cavity, medium size and medium depth; suture, medium deep; color, pale green; down, medium; skin, thick and tough; flesh, greenish white, tender, firm, juicy, sweet, and quality good; freestone; ripens during first half of August; tree very vigorous and a medium heavy bearer.

(10) Designated as D23; classification, Spanish; fruit, ovate, pointed, and medium in size; cavity, broad, shallow, and flaring; suture, medium deep; apex, medium long and pointed; color, greenish white; down, medium; skin, medium thick, tough; flesh, greenish white, tender, juicy, subacid, and quality poor; freestone; ripens between September 1 and 15; tree vigorous and a rather shy bearer.

As will be observed from the descriptions, several desirable peaches of the South China type, or at least showing a predominance of this strain, were produced. In quality and flavor they resemble very closely the Honey peach and are valuable as new varieties because by their different periods of ripening they permit the extension of the season of this class of peaches.

Table IV gives the average ripening dates, as shown by the 3 years' record, of the named varieties of the South China group on trial in the variety orchard, together with those that might be added from the Mexican seedling orchard.

TABLE IV.—*Average ripening dates of South China peaches and added seedling varieties at the San Antonio Experiment Farm.*

Variety.	Source.	Ripens.	Variety.	Source.	Ripens.
S. P. I. No. 32372	Mexican seedling	June 26	S. P. I. No. 32379	Mexican seedling	July 24
Honey	Variety orchard	July 4	Florida Gem	Variety orchard	July 30
Triana	do	July 8	S. P. I. No. 32376	Mexican seedling	Aug. 6
Taber	do	July 15	Climax	Variety orchard	Aug. 8
Pallas	do	July 17	S. P. I. No. 32380	Mexican seedling	Aug. 13
Imperial	do	Do.	S. P. I. No. 32373	do	Aug. 21

It will be observed from this table that even by limiting the selection to those of the South China race, the peach season may be extended to cover nearly two months, while by the addition of the Early China, which, according to Mr. Gilbert Onderdonk, ripens about a week or ten days earlier than the earliest of those listed in the table, the season may be extended still farther. By the additional use of some of the late ripening varieties of the Spanish race a still longer season may be secured.

There is a striking difference in the resistance to chlorosis of the different races of peaches. It is particularly noticeable that the seed-

lings of the South China type in the Mexican peach orchard are very susceptible to this disease, while those of the Spanish group are much more resistant. It should be noted in connection with these new varieties of the Spanish race that they are much more prolific than any grown in the test orchard except those of the Honey type. In fact, they are so far superior in production that it is doubtful whether a grower can afford to plant any of the older varieties mentioned rather than the new seedlings, even if the latter should prove to be slightly inferior as to quality. Furthermore, as the better varieties of the Spanish group are much more satisfactory to ship because of their large size, thicker skin, and firmer flesh, they may prove to be better suited to commercial production, though the fruit is distinctly more acid than that from the South China varieties.

PLUM.

Of all the fruits tried at the experiment farm, the plum is the most reliable producer and appears to be the best adapted to San Antonio conditions. The trees flower somewhat later than peach trees and consequently escape much of the late frost injury. Table V shows the varieties that have been under trial sufficiently long to justify tabulating. Of these, 12 varieties were set out in the spring of 1906, and the remaining 4 in the following spring.

TABLE V.—*Varieties of plums tested, showing the class to which each belongs, the number of years fruited, and the character of the crop, San Antonio Experiment Farm, 1906 to 1913, inclusive.*

Variety.	Class.	Origin.[1]	Fruited.	
			Years.	Size of crop.
Abundance	Japanese	Prunus triflora	3	Good.
Bartlett	Hybrid	Prunus triflora × Prunus simonii	3	Fair.
Burbank	Japanese	Prunus triflora	3	Good.
Eagle (*Beauty*)	American	Prunus angustifolia	4	Fair to good.
El Paso	do	do	4	Good.
Excelsior	Hybrid	Prunus triflora × Prunus munsoniana	3	Fair.
Golden Beauty	American	Prunus hortulana	3	Do.
Gonzales	Hybrid	Prunus triflora × chance seedling	5	Good.
Indian Chief	American	Prunus munsoniana	4	Do.
Lone Star	do	Prunus angustifolia	2	Poor.
McCartney	do	do	4	Good.
Pottawattamie	do	Prunus munsoniana	2	Poor.
Terrell	Hybrid	Prunus triflora × (?)	4	Fair to good.
Transparent (yellow)	American	Prunus angustifolia	4	Do.
Wickson	Hybrid	Prunus triflora × Prunus simonii	3	Do.
Wooten	American	Prunus munsoniana	2	Fair.

[1] The origin of the plums was obtained from "Plums of New York," by U. P. Hedrick, assisted by R. Wellington, O. M. Taylor, W. H. Alderman, and M. J. Dorsey.

The most successful plums in the test, orchard quality and productivity considered, are the Gonzales, Burbank (fig. 4), Wickson, Eagle, and Terrell varieties. The Transparent and Wooten are American sorts, and, although they yield good fruit for home use, they are not as valuable to the average grower as those of the Japanese class or some of the hybrids.

The Gonzales and Burbank varieties are rather inclined to overbear, often requiring thinning to produce the best fruit. The season of 1913 was unfavorable for plums because of a severe spring frost, which occurred March 17 and killed the fruit of many of the varieties. In spite of this frost the Terrell plum set a fair crop, while the Gonzales made an excellent yield of fruit. As these varieties were in blossom on March 1 and March 5, respectively, it would seem that they are more resistant to the cold than other varieties.

It should be borne in mind that there are several other varieties of the Japanese sorts, as well as of hybrids between them, that are

FIG. 4.—A bearing tree of the Burbank plum. This variety is well adapted to the San Antonio region of Texas, being of good quality and a reliable bearer. (Photographed July 8, 1912.)

not included in the table. As all representatives of these groups that have been tested have proved successful, it is probable that there are still other varieties that will do well. It is very evident that these three groups of plums are adapted to a much wider range of climatic conditions than are the peach varieties that have proved reliable in the San Antonio section.

PEAR.

Little work with pears has been done on the experiment farm, but observations made on neighboring farms, particularly that of G. A. Schattenberg, at Boerne, Tex., form the basis for some conclusions.

Some few plantings of pears have been made in the vicinity of San Antonio and have given varied results. The soils richest in lime, especially those with limestone gravel very near the surface, are not adapted to the culture of pears. The following varieties have been tested: Bartlett, Kieffer, Kruger, Le Conte, Magnolia, Russet, Sand, Smith, Vermont Beauty, and Early Wilder.

From the behavior of these varieties it would appear that the pear is less promising than the peach and the plum. The trees respond vigorously to a slight increase in altitude. Black lands lying north of San Antonio can produce successfully fruit of the Le Conte and Kieffer varieties, the latter being the more successful. Either of these varieties appears to succeed best when worked on Le Conte seedling stock. A recent oriental introduction of wild pear is being tested, which gives promise of exceptional value as a stock for species of Pyrus or Malus grown in this soil.

Pears in this locality are not free from the disease known as pear twig-blight, but climatic conditions are such that the disease is not severely destructive, and many seasons pass without its appearance, even in infected orchards.

Mr. Schattenberg, of Boerne, has been testing pears since 1892 and during the period has grown a large number of varieties. Boerne is located at an elevation of about 1,400 feet, about 700 feet higher than San Antonio, and though the rainfall is somewhat greater the soil is very similar. Mr. Schattenberg believes that from a commercial standpoint the pear is more promising than any other fruit in sections having similar conditions.

As a class the European varieties do not fruit well, and the fruit is of such poor quality that difficulty is found in marketing the crop. There are, however, a few exceptions to this, as, for instance, the Bartlett, Howell, Duchess, and Guyot varieties. The Bartlett and Angouleme develop such awkward shapes and grow so large that they are frequently unmarketable. The Howell, when dwarfed by working on quince root, is a valuable variety. The best of them all, however, is the Guyot.

The oriental hybrids are the best and most reliable. While rather low in quality, they bear regularly and abundantly. Mr. Schattenberg believes that the Kieffer is the best of this group. Besides the Kieffer the other varieties recommended are the Le Conte, Smith, Garber, Katy (of Texas), Golden Russet, and Magnolia, but for profitable commercial orcharding the Kieffer is far superior to all others in quality and as a market pear. The trees of this variety are inclined to overbear, and severe thinning has to be practiced in most seasons.

It is the opinion of Mr. Schattenberg that pear growing in western Texas on a commercial scale is a profitable venture when the under-

taking is backed by experience, provided the right varieties are chosen and care is used in selecting the locality. His 30-acre orchard, 22 years old, with trees planted 20 by 20 feet apart, which is too close, has frequently borne 200 to 250 bushels to the acre, and some individual trees in favorable situations have borne from 8 to 10 bushels to the tree. This orchard doubtless would have done better had it been possible to irrigate during some of the long, dry periods, although it received clean cultivation after reaching the bearing stage.

GRAPE.

Grape growing in the immediate vicinity of San Antonio has been limited to varieties of rather poor quality, which are used largely for the production of wine. The better varieties of table grapes that have been under trial have not survived the adverse soil conditions. Their failure is due largely to root-rot. Chlorosis, which occurs frequently, also indicates that the lime in these soils is in excess of the tolerance of the better varieties of the table grape. The country about San Antonio is rich in species of native grapes which thrive under these conditions. Some of the most successful of the named varieties under trial are those that have resulted from crosses between cultivated varieties and native species. However, there is an extensive area of red sandy-loam soil adjoining the black lands on the south that should produce excellent grapes if root-rot and chlorosis can be avoided or controlled. The following grapes have been tested on the experiment farm: Bell, Berckmans, Brilliant, Champanel, Cloeta, Eden, Flowers, Goethe, Headlight, Lukfata, Mericadel, Mish, Norton, Thomas, Valhallah, Wapanuka, Wise, Xenia, and Gapotum. Most of these have been unable to survive, because of their susceptibility to root-rot and chlorosis. The varieties that have proved best adapted to this region are Valhallah and Lukfata, although the quality of the fruit is not high. Except for home consumption or for the production of wine, no varieties of grapes have been found that are altogether satisfactory.

In this connection it is of interest to show the parentage of the two grapes mentioned above, as given by the late Mr. T. V. Munson in "Foundations of American Grape Culture." Lukfata was obtained by crossing *Vitis champini*, a native Texas species, with Moore. Valhallah is a cross between Elvicand and Brilliant, and Elvicand is a cross between Elvira and *Vitis candicans*, the native mustang grape.

DEWBERRY.

While none of the small fruits, such as berries, have been tested at the experiment station, it seems advisable to mention the dewberry because of its adaptability to this section, being a native of Texas. It appears to be tolerant of a wide range of soil conditions. Mr. T. R.

Dillon, who has been growing dewberries for several years a short distance south of the station, has been successful on soil that is somewhat more sandy than that at the experiment farm. The area devoted to the crop has varied from 5 to 10 acres. Mr. Dillon considers this one of the most profitable fruit crops for this locality. At the present time he has four varieties—Haupt, Austin May, McDonald, and Rogers. Of the four, he considers Austin May the best, with Rogers second. The Rogers is a particularly desirable variety, as it ripens early. There is some danger of late frost injuring the crop, and occasionally the yield is materially decreased because of early flowering.

PERSIMMON.

A collection of 12 budded varieties of the Japanese persimmon was placed in the experimental orchards in 1906 and 1907. These included both the astringent and the nonastringent types, as follows: Astringent—Yemon, Okame, Hachiya, Tsuru, Triumph, Tanenashi, and Costata; nonastringent—Taber's 129, Yedoichi, Hyakume, Taber's 23, and Zengi.

A number of these varieties have done very well, fruiting regularly since reaching bearing age, and some have produced exceptionally heavy yields for small trees. The varieties that have proved the best are the Okame, Tsuru, Taber's 129, Yedoichi, Hachiya, Hyakume, and Zengi. Of these varieties, the trees of Okame and Taber's 129 are the most prolific and vigorous. Other very highly prized varieties have been added to the collection recently, but as yet have not reached the bearing age.

The persimmon is very susceptible to chlorosis, and many of the varieties under trial have been severely injured by this disease. The *Diospyros virginiana*, which has been used generally as a stock for the Japanese sorts, is very susceptible to this disease and should not be used as a stock in this section.

Several recent importations by the Office of Foreign Seed and Plant Introduction that are under trial here promise to be valuable additions to the list, both for fruit production and for stocks. Among them may be mentioned *Diospyros lotus* (S. P. I. 17906), which has been found to be the most resistant to the soil difficulties of any of the different sorts under trial. (See figs. 5 and 6.) The fruit of this tree is very small and is of little value, however.

PECAN.

No other branch of horticultural endeavor in the San Antonio section promises to afford so broad a field for selection and improvement as the nut trees.

Already a large number of recognized varieties are being tested in this part of the State and undoubtedly there are now in the forests

numerous individual trees bearing nuts of sufficient merit and in sufficient quantity to justify their being propagated as new varieties of special promise for this section.

Twelve standard varieties are growing at this station. The original experiment embodied 19 varieties planted in 1909. These are being tested with much care under good dry-farming conditions. Such results as are indicated here, together with wide and varied observations of the natural home of bearing trees and the behavior of comparable plantings in other situations, all indicate that care should be exercised in selecting locations for pecan plantings. Successful tree growth and fruiting should not be expected when the pecan is planted in a soil where underground water is not within reach of the roots. The surface application of water on most of the higher land of this section does not appear to fulfill the needs of the pecan. As the tree approaches bearing age, the roots must penetrate deeply into soil which is drawing water from the underground water table; then the pecan succeeds and grows to be the most stately tree of Texas. The contention advanced by some enthusiasts that since the pecan is native it can be grown under a great variety of conditions is erroneous. It should be borne in mind that the pecan in this part of Texas is distinctly a river-bottom tree and that the mere application of light surface irrigations sufficient for many other trees will not satisfy its needs.

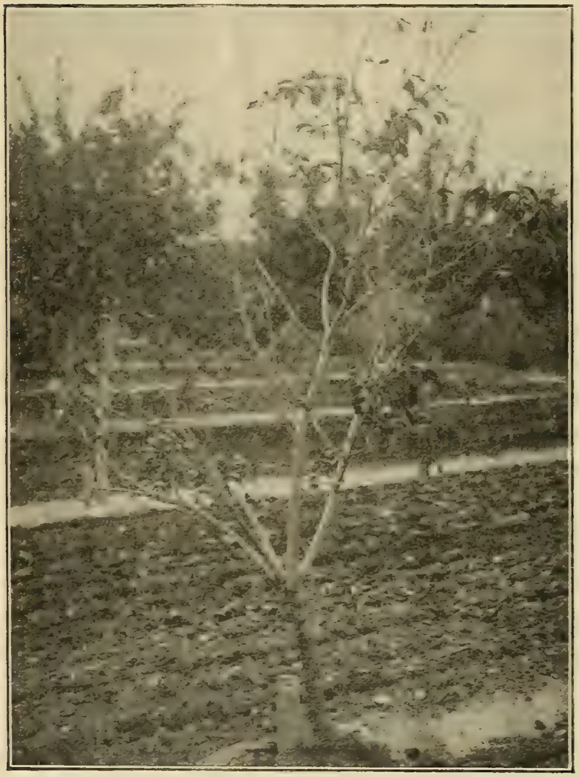

FIG. 5.—A tree of *Diospyros kaki*, or Japanese persimmon, which is nearly dead from chlorosis. This tree has been in its present location for eight seasons. The only persimmons that have been found that are resistant to chlorosis and root-rot are the native *Diospyros texana* and *D. lotus*. Compare with figure 6. (Photographed September 16, 1913.)

THE LESS IMPORTANT FRUITS.

The fruit crops already enumerated are all that the writers are now prepared to recommend for planting in farm orchards or gardens. Not all of them will be found suited to every farm, but it is believed that some of them may be used on each farm, and in most cases all of them may be used if desired.

In addition to the lists of fruits which have been mentioned, many others have been under experiment at the San Antonio Field Station.

FIG. 6.—A tree of *Diospyros lotus*, an importation from China, which is a very promising stock for the Japanese persimmon. These trees appear to be immune to chlorosis and resistant to root-rot. The one here shown has been growing in its present location for seven seasons. Compare with figure 5. (Photographed September 16, 1913.)

Some of them have been found unsuited to local conditions, and the experiments with others have not yet progressed far enough to warrant final conclusions. There is apparently widespread interest in regard to the possibilities of many of these fruits, and requests for information regarding them are frequent and insistent. In order to meet this demand the following notes are included. It should be

understood, however, that the work is still in progress and later results may modify the conclusions here given.

Prune.—Prunes have not been on trial long enough to produce fruit. However, the young trees are vigorous and appear to be well adapted to the conditions, although this does not signify anything of importance. The varieties on trial here are the Italian, Giant, French, Epineuse, Tragedy, and Pond.

Apricot.—The Cluster, Royal, Moorpark, Early Golden, and Onderdonk apricots have been under trial since the spring of 1906. Several favorable seasons have passed since these trees were of a bearing age, but only a few fruits have yet been produced by any of the varieties. To judge by its behavior, this fruit is not adapted to San Antonio conditions, although a few seedling trees in the neighborhood are said to produce fruit regularly but of rather poor quality. Very often the apricot crop is ruined by frost because of its early flowering season.

Cherry.—The list of cherries that could possibly be of value under San Antonio conditions is very small. From the behavior of those tested and those observed elsewhere, the indications are that this fruit is not adapted to this locality. The Advance, Eagle, Napoleon, and a wild cherry from China were set out in the spring of 1911. The Compass (not a cherry in the pomological sense, as it is a cross between the Miner plum and the Dwarf Rocky Mountain cherry) and the Baldwin were set out in the following spring.

Nectarine and plumcot.—Such other drupe fruits as the nectarines and plumcots have been but little tested. The Crosby nectarine set out in March, 1907, has borne only one crop of fruit since it began to bear four years ago, and it behaves much the same as peaches of the unadapted type. A seedling nectarine occurring in the Mexican seedling orchard has made a vigorous tree, but has borne fruit sparingly and has a tendency to very irregular ripening. This nectarine, however, is of fair quality and may prove to be a good variety for some other locality. Its behavior in the seedling orchard as a tree and as to flowering and fruiting habits resembles closely that of the peach varieties not adapted to this section.

Apple.—Apples have been tested only in a small way at the station, but the behavior of other near-by plantings in similar soils has been observed. Very few trees have produced any fruit. Apparently this region is not suited to apple production. Many apples fail to grow into trees, remaining dwarfed and bushy. The only varieties observed that have been partially successful are the earliest sorts.

Citrus fruits.[1]—It is very doubtful whether even the hardy Satsuma orange grown in parts of Texas will thrive as far north as San Antonio

[1] The testing of citrus fruits at this station has been carried on in cooperation with the Office of Crop Physiology and Breeding Investigations, Bureau of Plant Industry.

unless grown in well-protected situations. A number of plantings have been made in this section, but none of the trees has survived. Plantings of other sorts have been made, but the only citrus trees that have proved hardy are certain varieties of citranges. These fruits were originated by crossing the common sweet orange with the hardy trifoliate orange.[1] The following varieties of these citranges have been under trial: Coleman, Cunningham, Morton, Rusk, Rustic, Savage, and Thornton. Of these the Rusk is the only variety that appears to be adapted to these conditions. The others either have died or made a very poor growth. This variety is bearing fruit for the first time this season.

One interesting feature in connection with this group of fruits is that the trees appear to be immune to the root-rot fungus, so fatal to many other fruit trees. Plantings have been made since 1908, but none of the trees has died from this cause so far as it was possible to observe, although several varieties died from other causes.

There is reason to believe that the Rusk citrange may make a good stock on which to work other citrus fruits in parts of Texas where the trifoliate stock is not adapted. This species has not done well at the experiment farm, whereas the Rusk citrange on its own roots has made an excellent growth. In addition to furnishing a useful fruit, the citrange can be used as a hedge, resembling very much the trifoliate orange, and it should be planted here in preference to that species.

Fig.—A collection of several varieties of figs, including the Mission, Magnolia, and others, has been grown without irrigation. The results indicate that the fig can not be grown successfully in this section without irrigation, and even with irrigation it is a doubtful crop because of winterkilling, except in protected situations. The plant is apparently exceptionally free from chlorosis, but is very susceptible to root-rot, and this disease may be a limiting factor in growing this fruit crop on a commercial scale, even under irrigation. While San Antonio is near the northern limit of the zone where the fig can be grown in Texas, because of low winter temperatures, still, when grown in sheltered situations near buildings or other protection, the trees will survive where temperatures fall much lower than those ordinarily experienced in San Antonio. The fig should by all means be included among the fruits produced for home consumption on the farm. It should be grown, if possible, where some protection is afforded and where an occasional irrigation is possible. The Mission and the Magnolia are the two varieties most generally grown in this vicinity, but several other varieties of the Adriatic type seem to be well adapted. The Smyrna type of figs can not be fruited in

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[1] Webber, H. J., and Swingle, W. T. New citrus creations of the Department of Agriculture. Yearbook of the Department of Agriculture for 1904, p. 221–240.

this climate, for the reason that the Blastophaga, the insect necessary for the fertilization of the fruit, will probably not endure the winter temperatures.

Walnut.—Another possibility of nut culture is the Persian walnut, which has already made rapid growth when budded or grafted on the native walnut, although the effort to grow it is at present wholly in the experimental stage. A number of grafts and buds have been worked on the native *Juglans nigra*, both at the station and for Mr. F. F. Collins, who has cooperated in this work. While the trees worked have not yet reached the bearing age, still with the exception of the first year, when they were severely frozen back, the Persian walnuts have made an excellent growth on this stock.

Almond.—Although doubtful for fruit production, owing to its early-blooming tendency, the almond makes a vigorous tree. A few nuts of the Nonpareil variety were secured in 1912 from a tree two years from planting.

Pistache.[1]—A rather complete collection of pistache trees, from which the pistache nut of commerce is obtained, is being tested here. None of the trees has fruited yet. Most of the species appear to be unadapted to these conditions, owing largely to their susceptibility to root-rot. Many of the trees have died from this disease.

Pomegranate.[2]—Although not producing a fruit of much commercial importance, pomegranates have proved to be as well adapted to the particular local conditions as any orchard plant tested, being very resistant to the adverse soil conditions fatal to many fruit trees. As ornamentals or for a hedge plant they are very useful, although occasionally there are winters when they will be injured by frost.

A variety test of 12 named varieties is being conducted, and also seedling pomegranates covering half an acre are being fruited with a view to obtain other varieties. A few pomegranate plants in a home garden will not be amiss, for good specimens of the fruit are delicious and refreshing.

The varieties that have been fruited are the Radinar, San Pipetos, Jative, Hermosilla, Papershell, Sweet, Ruby, Dessia, and Subacid. The varieties in this collection that have produced the best fruits are San Pipetos, Jative, and Dessia, while the Radinar, Papershell, and Subacid varieties have matured the heaviest crops. Plants of the San Pipetos and Jative have made the heaviest growth.

Jujube.—The jujube, or Chinese date (*Ziziphus* sp.), is one of the more promising new fruits, and the hardy types appear to be well adapted to San Antonio conditions. Two species, *Ziziphus mauri-*

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[1] The testing of pistache trees at this station has been carried on in cooperation with the Office of Crop Physiology and Breeding Investigations, Bureau of Plant Industry.

[2] The testing of pomegranate varieties at this station has been carried on in cooperation with the Office of Alkali and Drought Resistant Plant Investigations, Bureau of Plant Industry.

tiana (S. P. I. 28129) and *Z. oxyphylla* (S. P. I. 28130), are not hardy. Both *Ziziphus sativa* and *Z. jujuba* are perfectly hardy and have made an excellent growth. Many of the better varieties so highly esteemed in China are being assembled at this station. As yet this fruit is more of a novelty than a product of commercial value, but when properly prepared it is considered a delicacy in this country as well as in China.

Quince.—Only one variety of quince has been tested, and it has not made a satisfactory showing. It is very probable that this fruit is out of its zone here.

Olive.—The Chemlaly and Aberkan olives have been grown here for several years, but the climate appears to be too severe for them.

Date.—Although it is probable that the San Antonio climate is entirely too humid for the date to ripen fruit, the seedlings grown are quite hardy, and the tree is valuable as an ornamental. Temperatures of 12° F. have been experienced without killing the plants, although the leaves are generally injured by temperatures below 20° F.

TESTING RESISTANT STOCKS.

One of the most promising and important lines of horticultural investigation at the present time is the determining of stocks resistant to the local soil troubles. Not only is there a great difference in the power of resistance in different species, but there is also a very noticeable difference in the resistance of different varieties of the same species. As an illustration, many of the seedlings of the Spanish race in the Mexican peach orchard are quite immune to chlorosis, while almost invariably those of the South China group are very susceptible. Certain varieties of persimmon are resistant, while others are severely affected.

The richness of the native flora in economic plants, some of which may be utilized as stocks and others for hybridizing experiments, together with those which have been assembled from this country and by the importation of those which have indicated their susceptibility or resistance to soil disorders, forcibly emphasizes the importance of this line of effort. This work has received special attention the past three years. The preliminary results indicate very distinctly not only that many of the better varieties of fruit which are not considered adapted to these conditions may be utilized, but that additional fruits not commonly grown here may be added to the list.

Persimmon.—One of the most interesting new stocks now under test is the native Texas persimmon (*Diospyros texana*). This is being used as a root for both the American and the Japanese persimmon. It has been found very difficult to work other persimmons on this stock, and many previous attempts have resulted in failure where ordinary methods were used. During the spring of 1912 a number of

good unions were made by the inarch-graft method. These are now growing in the experimental orchard. Both the American and the Japanese sorts seem to be growing fairly well on this stock, but the danger feared is that *Diospyros virginiana* and *D. kaki* will both outgrow the root of *D. texana,* or at least that the trees will be dwarfed and checked in growth for this reason. *Diospyros texana* is distributed over a wide stretch of semiarid country in southwestern Texas, where soils are shallow and very calcareous. The tree has never been known to die from root-rot. Its drought resistance is exceptional, but it apparently responds to a more generous supply of moisture.

A recent importation of a wild persimmon from China, *Diospyros lotus* (S. P. I. 17905 to 17907), by the Office of Foreign Seed and Plant Introduction, is extremely promising as a stock. (See figs. 5 and 6.) Five trees set out in the spring of 1907 have made an excellent growth and are quite resistant to the soil difficulties. The behavior of the trees thus far indicates that this species is entirely at home here. It may prove to be as good a stock as the native persimmon because it seems to be quite as resistant to the soil difficulties, and it may prove to be even better because of its more rapid growth.

Pyrus betulaefolia (S. P. I. 21982), a wild pear from China which has been previously referred to, gives indication of being a good stock for pears in this section. The appearance and growth of the trees here indicate that the species is more resistant to those soil difficulties that noticeably affect the pear on its own roots.

Grape.—At this time there are no table grapes of special value that can be grown here on their own roots. The crown grafting of the native mustang grape (*Vitis candicans*) has been successful, although on the uplands this grape does not do as well as some of the cultivated varieties. There may be other native grapes or hybrids between them and the cultivated varieties that will do well for stocks, but of the many tested at this station none has appeared so promising as the variety known as Lukfata. Eight vines of this variety have been under trial for six years, and none of them has shown susceptibility to either root-rot or chlorosis, the two most serious diseases affecting the grape. There is good reason to believe that by the utilization of these resistant stocks the list of grapes adapted to this section may be materially increased, thus giving an entirely new outlook for grape production.

Walnut.—The Persian walnut is not grown in this part of Texas at this time. Repeated trials have been made, which resulted only in failures. This was due undoubtedly to the fact that the walnut was worked on a stock that was not able to survive these soil conditions. Both native species of the walnut, *Juglans nigra* and *J. rupestris,* are proving to be adaptable stocks for the Persian walnut. Experiments in the propagation of the Persian walnut on these

stocks indicate that patch budding and crown grafting are the most successful methods to be employed. Ring budding gives reasonably good results, but with this method more buds are lost after the union has been formed than is the case with patch budding.

A large number of seedlings of the native black walnut (*Juglans nigra*) were grown by Mr. F. F. Collins, and several of these trees have been budded. With the exception of the first year, the winter of 1911–12, when the young growth was frozen back, a good growth has been obtained. A sufficient number are being grown at this time to demonstrate the value of this stock.

Stone fruits.—Native plums are being used experimentally as stocks for stone fruits. The sorts commonly known as Tenehah

FIG. 7.—Two rows of *Amygdalus davidiana*, a peach from China introduced by the Office of Foreign Seed and Plant Introduction, which is a very promising stock for stone fruits. These trees were set out in January, 1909. (Photographed September 16, 1913.)

(*Prunus munsonii*), American (*Prunus americana*), and hog (*Prunus rivularis*) are included in this test. It is not expected that all of these species will be useful on a large scale, but the vigorous growth of the different species under very adverse conditions on the limestone hills about San Antonio proves their hardiness.

A wild peach from China (*Amygdalus davidiana*, S. P. I. 21227), which bears a fruit of no value, has proved to be unusually well adapted to San Antonio conditions. (See fig. 7.) So far it has proved to be resistant to both chlorosis and root-rot. One orchard of about 30 trees, set in January, 1909, has survived without the loss by disease of a single tree. This species is being tested as a stock for peaches, plums, almonds, and apricots. The only serious drawback of this tree so far noted has been its failure to produce

seed. In this respect it behaves in this locality not unlike the unadapted peach varieties.

Trees of the Spanish group in the Mexican seedling peach orchard are relatively resistant to the soil difficulties and give every indication of furnishing a better stock on which to work stone fruits than peaches of the unadapted type. This orchard is now being kept chiefly for the production of such seed, in order to supply desirable stocks for local peach plantings.

SUGGESTIONS ON ORCHARD MANAGEMENT.

Cultivation.—Orchard cultivation of all kinds around San Antonio without irrigation must necessarily be much more intensive than in

FIG. 8.—Orchard cultivator used in the experimental orchards to establish a mulch and keep down weeds. Clean culture is absolutely necessary for successful fruit production in the San Antonio section. (Photographed July 12, 1912.)

more favored sections because of the uneven distribution of the rainfall. Clean culture, especially when the trees have reached the bearing stage, is absolutely essential, for all available moisture must be conserved. As much care must be given the orchard as is given cotton or corn, if successful results are to be obtained. The best method of orchard culture, rigorously practiced at the San Antonio Field Station, is to keep a 3-inch or 4-inch earth mulch on the ground throughout the growing season. After every rain of any consequence, from early spring until fall, the orchards have been gone over, either with an orchard cultivator (fig. 8) or a spike-tooth harrow. If the orchard cultivator is equipped with sweeps to supplement the ordinary shovels and these sweeps are used when the

weeds appear, there will be practically no necessity for hand labor in keeping the orchard free from weeds, except near the trees.

Planting distances.—The distances apart of planting the trees should be greater than is customary in regions of greater rainfall. In the test orchards the trees were spaced 15 to 17 feet apart, but this is much too close for the trees to do well after they reach full size. Peach trees should be not less than 25 feet apart, and a greater distance may be advisable. Plums may be planted somewhat closer together, but it will be found in the end that wide spacing will give more satisfactory results.

Green-manure crops.—The soils of the San Antonio region are often lacking in organic matter. Green-manure crops or stable manure will do much to correct this condition. Cowpeas were first used as a green-manure crop, planted late in July. As that is the season of the year when droughts are most likely to occur, it was found that this crop was not wholly satisfactory. Later, Canada peas were introduced as a winter-cover and green-manure crop. This has proved the best of any so far tried. The Canada peas should be planted as soon after the first of October as possible, or at about the time oats are ordinarily sown. Satisfactory results have been obtained by planting with an ordinary grain drill, seeding at the rate of about 90 pounds per acre. The crop is plowed under the latter part of February or early in March. The best variety so far tested is known as the Golden Vine (S. P. I. 30134). It has been grown here for the past two winters in comparison with several other varieties and is the only one that has survived a temperature as low as 15° F. above zero.

SUMMARY.

There is comparatively little authentic information regarding the possibilities of fruit culture in the vicinity of San Antonio. Consequently, the greater part of the farming population is poorly supplied with fruit.

The horticultural work of the San Antonio Field Station included not only the testing of a large collection of varieties, but tests of resistant stocks have also received much attention.

A number of limiting factors govern fruit production in this region. The soil conditions are unfavorable for many fruits. The climate is too severe for such fruits as oranges and olives and too mild for apples and cherries. The rainfall is sufficient for most fruits if the trees are spaced at somewhat greater distances than in more humid climates.

The early attempts at peach growing were made with seedlings from the early Spanish importations. The later introductions consisted largely of varieties of the North China, Persian, and Peen-to races, none of which has proved wholly successful.

With the introduction af the Honey peach a new type was found which has proved particularly well adapted to the conditions. The

Pallas, Honey, Imperial, and Climax have proved to be the most reliable and promising of the varieties so far tried.

A large number of varieties of the American and Japanese classes of plums do well. The best among the 14 varieties under trial are the Gonzales, Wickson, Burbank, Excelsior, Eagle, and Terrell.

Of the other stone fruits tested, which include cherries, nectarines, and plumcots, it was found that none of the varieties under trial has given good results.

Pears do fairly well on the higher lands. The Kieffer is the best variety for general planting.

Native grapes are abundant in the San Antonio area, and some of the cultivated varieties that are related to these wild species may be grown. None of them, however, possess qualities that justify their use as table grapes.

Of the small fruits, dewberries have been found to return good profits when properly cared for.

None of the citrus fruits has done well, with the exception of the Rusk variety of citrange. This variety is perfectly hardy and has made good growth.

Figs seldom go through the winter without being injured by cold, except in protected locations. The Mission and Magnolia are probably the best varieties.

Persimmons are included among the fruits that do well. The varieties that have given the most satisfactory results are the Okame and Taber's 129.

The native pecan is distinctly a river-bottom tree. When grown where underground water is available it does well, but results on the uplands have been disappointing, even with irrigation.

The Persian walnut does not do well on its own roots, but when worked on either *Juglans rupestris* or *J. nigra* it makes a good growth.

Almonds have a tendency to flower so early that they are injured by frost and rarely fruit.

Pistache trees, while making a vigorous growth, are so susceptible to root-rot that it is doubtful whether they can be grown successfully.

Pomegranates make a vigorous growth and fruit well, but are occasionally injured by cold.

The jujube, or Chinese date, is one of the promising new fruits.

Although the date palm can be grown, the climate is probably not suitable to the production of the fruit.

The cultivation of orchards must be more intensive than where there is a greater rainfall. Clean culture during the summer is absolutely essential.

Canada peas have been found to be the most satisfactory green-manure crop.

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No. 163

Contribution from the Bureau of Animal Industry, A. D. Melvin, Chief.
January 12, 1915.

A FIELD TEST FOR LIME-SULPHUR DIPPING BATHS.

By Robert M. Chapin,
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INTRODUCTORY.

The purpose of this paper is to describe a portable testing outfit devised by the writer and employed by the Bureau of Animal Industry for estimating the strength of lime-sulphur dipping baths used in official dipping under regulations now in force.[1] A description of the outfit will be of interest to Federal and State officials concerned with the supervision of dipping, to private parties who wish to control the composition of their dipping baths, and to manufacturers whose dips are subjected to test. This method, however, is intended only for field use; it can not replace in the laboratory the more accurate methods of analysis approved by the Association of Official Agricultural Chemists.

Lime-sulphur dipping baths, whether homemade or proprietary, are essentially composed of two substances in solution, both of which contain sulphur, namely, calcium polysulphid and calcium thiosulphate. The Bureau of Animal Industry has no present proof that calcium thiosulphate is of any value for the treatment of scabies in either cattle or sheep, and pending further investigation, accordingly, must attribute the efficiency of dipping baths solely to the sulphur present in the form of calcium polysulphid.

Many factors may influence the strength of lime-sulphur dipping baths. In the first place, one of the raw materials, lime, is a substance of notoriously uncertain composition as commercially obtainable, and, further, it deteriorates on storage, so that a homemade concentrated dip may turn out much weaker than its maker has cause to suppose. In the second place, solutions of calcium polysulphid are decomposed by contact with air, so that a bath may notably deteriorate even during a single day's dipping. In the

[1] Bureau of Animal Industry Order 210, issued June 18, 1914; reg. 3, sec. 9, p. 19, and reg. 4, sec. 5, p. 23.

Note.—This bulletin describes a portable testing outfit for estimating the strength of lime-sulphur dipping baths; it is of interest to makers and users of such baths, as well as to officials charged with the enforcement of dipping regulations.

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absence of a test one faces the alternatives of strengthening slightly used baths by guesswork or of discarding them entirely. A field test is therefore essential to the prosecution of dipping in a manner which shall be at the same time effective and economical.

METHOD OF EXECUTING THE TEST.

The test here described employs the well-known reaction between soluble sulphids and iodin[1] in neutral solution, whereby sulphur is precipitated and a metallic iodid is formed. It therefore directly estimates, not sulphur, but the metal—in this case calcium—combined with sulphur in the form of sulphid or polysulphid. Only in case that sulphur is combined with metal in unvarying proportion can the method also estimate exactly the amount of sulphur present. Theoretically this requirement is not met in the case of lime-sulphur baths, the ratio of lime to sulphur in the mixture of calcium polysulphids which may be present being susceptible to considerable variation. As a matter of fact, however, practical experience of the Bureau of Animal Industry with the test in the field indicates that the ratio in baths prepared after the formulas specified for use in official dipping is near enough to a fixed figure to render the test of entirely adequate accuracy for practical purposes. The ratio provisionally adopted is 4.6 atoms of sulphur to each atom of calcium, or, by weight, 147.5 parts sulphur per 40.07 parts calcium.

Briefly, the method of test involves the addition of standard iodin solution to a measured quantity of bath until the resulting liquid no longer gives color with a dilute alkaline solution of sodium nitroprussid, showing that calcium polysulphid has been entirely decomposed. The amount of iodin added to reach this point is then a measure of the amount of "sulphid sulphur" in the bath. The outfit is pictured in figure 1, and the parts composing it will be described in detail.

PREPARATION OF THE OUTFIT.

I. *The case.*—The carrying case for the outfit is a rectangular box with a hinged cover, made of $\frac{5}{16}$-inch oak, of inside dimensions $7\frac{1}{2}$ by $5\frac{1}{8}$ by $1\frac{7}{8}$ inches. The interior construction, of softer wood, is sufficiently indicated in the diagram. The case must be strongly mortised or nailed together, not simply glued, and should be varnished or painted.[2]

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[1] Titration with iodin for determining the "monosulphid equivalent" of lime-sulphur dips seems to have been first seriously proposed by Harris (Michigan Agric. Coll. Exp. Sta. Techn. Bull. No. 6, Jan., 1911). There may be some question regarding the accuracy of the method for exact laboratory analysis, but the uncertainty is not of sufficient seriousness to affect its usefulness for the present purpose.

[2] The cases used by the bureau are painted yellow (yellow being the color of sulphur) to avoid confusion with the similar test case used for arsenical baths (see Department of Agriculture Bulletin 76) which is merely varnished.

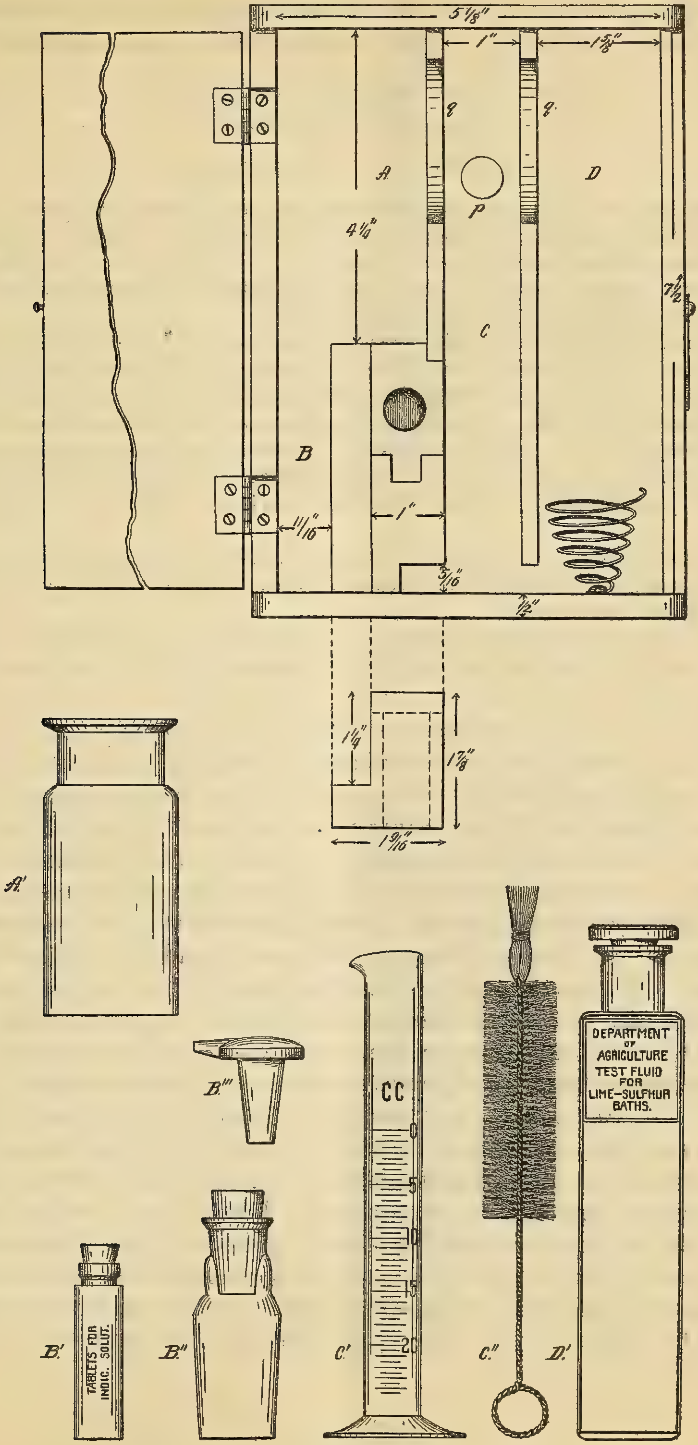

FIG. 1.—Test outfit for lime-sulphur dipping baths.

On the inside of the cover of the case is glued a printed instruction sheet, protected by a pyroxylin varnish, which reads as follows:

UNITED STATES DEPARTMENT OF AGRICULTURE.
Bureau of Animal Industry.

TEST OUTFIT FOR LIME-SULPHUR BATHS.

1. Mix bath well, let settle for a few minutes, then fill clean, dry graduate with bath, setting *top* edge of surface on the zero mark, and pour (draining out drops) into clean, wide-mouthed bottle.

2. Rinse graduate with clean water (or with a little of the test fluid) shake out adhering drops, and fill to zero mark with test fluid.

3. While gently swirling bottle containing the bath pour in test fluid from the graduate until the yellow color of the bath becomes faint. Then let the contents of the bottle come to rest and gently drop on the surface one drop of indicator solution from the dropping bottle. Note if a violet color appears where the indicator solution mixed with the bath. If color appears add a little more test fluid from the graduate, mix, and test again with a drop of indicator solution. Continue thus until a drop of indicator solution fails to produce any color, avoiding the addition of excess of test fluid.

The number of cubic centimeters of test fluid added to just reach the point where color with indicator solution fails to appear represents tenths of one per cent of "sulphid sulphur" in the bath.

Note.—The indicator solution should not be more than one week old. Prepare fresh solution by dissolving one "tablet for indicator solution" in 15 c. c. clean water in the bottle.

II. *The utensils.*—Bottle A', fitting into compartment A of the case, is an ordinary 3-ounce wide-mouth bottle of clear glass.

Measuring cylinder C', fitting into compartment C, may be of ordinary type though preferably it is graduated to read down only, and is provided with an especially deep lip to prevent the liquid from running down the outside when small quantities are poured out. C'' is a bristle brush for cleaning. It will be noted that the partitions of compartment C are cut away as indicated to admit the foot of the cylinder. At the point (p) on the back wall of the case is cemented a $\frac{3}{8}$-inch pad of cork to protect the cylinder from breakage. The brush C'' is put into compartment C after the cylinder, thus protecting the latter from contact with the cover of the closed case.

III. *The reagents.*—The "test fluid,"—that is, the standardized iodin solution—is contained in the bottle D', which may be a special square bottle to fit compartment D, or, more readily obtainable, a 4-ounce standard-shaped "sample oil" bottle, preferably of amber glass, and provided with a "flat-hood" glass stopper. The test fluid is of such strength that in the actual performance of the test each cubic centimeter of it employed represents one-tenth of 1 per cent of sulphid sulphur in the bath. Allowing for the meniscus, etc., it

may be assumed nearly enough for practical purposes that the amount of bath delivered by the cylinder is 24 c. c. Each cubic centimeter of test fluid therefore must be actually equivalent to 0.024 gram of sulphid sulphur in order to be apparently equivalent to 0.1 per cent in the execution of the test. Now, a "normal" solution of Ca:4.6S would contain 0.07376 gram sulphur per cubic centimeter; that is, the strength of the test fluid should be $\frac{0.024}{0.07376}=0.325$ N. In preparing it 44 grams iodin and 88 grams potassium iodid are dissolved in water and made to 1 liter, and the strength of the solution is then adjusted against sodium thiosulphate or arsenious oxid. For example, 50 c. c. of a tenth-normal solution of either of the above standards should require 15.38 c. c. of test fluid of correct strength. The test fluid should, of course, be kept in glass-stoppered bottles only, and in a dark, cool place.

The tablets for indicator solution are prepared after the following formula:

	Grams.
Milk sugar, powdered	12
Sodium nitroprussid, powdered	20
Sodium carbonate, monohydrated, powdered	100

Mix, moisten with 50 per cent alcohol, granulate, and dry at room temperature, then mix granules with 3 per cent of powdered talcum and compress to tablets of 0.255 gram. The tablets are put up in a small glass tube or vial, reinforced against breakage by a glued strip of paper rolled several times around it and folded in at the bottom. After corking and labeling the whole is dipped in paraffin. The tablet vial is put into the left-hand side of compartment *B*, followed by the rubber-stoppered bottle *B''* for indicator solution. This is the standard "TK" dropping bottle, flat stopper, 15 c. c. size, and must be made of amber glass, since the indicator solution is rapidly decomposed upon exposure to light. The glass stopper *B'''* of the dropping bottle is carried in the hole at the right-hand side of compartment *B*, since if left in the bottle for a considerable length of time it may stick fast through the action of the alkaline solution upon the glass.

If the test can not be executed at the vat side the sample of bath should be taken at the vat side in the bottle in which it is to be forwarded. The bottle should be filled to the neck, tightly stoppered, and the stopper and lip of the bottle should be dried and well covered with sealing wax or some similar material, in order to exclude air. Even with these precautions the test must be executed with as little delay as possible, for it has been found that some samples of used

baths decompose upon standing in stoppered bottles, with the result that hydrogen sulphid is formed, and the accuracy of the test is consequently vitiated. The cause and mechanism of this change calls for further study, but there is at present reason to believe that it may be brought about through the action of microorganisms in the bath.

Obviously, if the outfit is used for testing concentrated dips, such should first be diluted with sufficient water to bring the probable content in sulphid sulphur to not much over 2 per cent. Such dilutions may readily be made with the measuring cylinder and wide-mouth bottle provided in the outfit.

UTILIZATION OF RESULTS AFFORDED BY THE TEST.

The object of using such a test as that described is to maintain dipping baths at uniform and effective strength. The test merely indicates the actual strength of the bath, and if the bath is found to be too weak there then remains the task of calculating how much concentrated solution must be added in order to bring it up to the proper strength. Therefore the following tables[1] have been prepared to render the desired information obtainable with a minimum of calculation.

The use of the tables is very simple. For instance, suppose a sheep bath amounting to 1,250 gallons to contain 1.1 per cent sulphid sulphur, as shown by the test, and suppose that a concentrate containing 24 per cent sulphid sulphur (dilution figure 1 to 15) is to be used to strengthen the bath. The table for standardizing sheep baths shows directly that for every 100 gallons of bath in the vat there is needed 1.8 gallons of concentrate, or for the whole, $12.5 \times 1.8 = 22.5$ gallons of concentrate, which quantity is simply to be measured out and added to the bath already in the vat. However, since the bath continually becomes weaker, it is advisable to add somewhat more concentrate than just enough to attain standard strength.

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[1] The formula used to calculate the figures in these tables is $x=100\frac{c-a}{b-c}$, in which a=percentage of sulphid sulphur found in the bath by test; b=percentage in the concentrate, and c=standard percentage in bath for dipping.

STANDARDIZING LIME-SULPHUR DIPPING BATHS FOR SHEEP.

Table showing quantity of concentrated dip to be added to each 100 gallons of bath to restore same to standard strength (1.5 per cent sulphid sulphur).

Percentage (on volume) of sulphid sulphur in concentrate.	Dilution figure of concentrate.	Percentage of sulphid sulphur in bath by test—						
		0.8	0.9	1.0	1.1	1.2	1.3	1.4
		Gallons of concentrated dip to be added to 100 gallons of bath.						
Per cent.								
4.5	1 to 2	23.0	20.0	17.0	13.0	10.0	6.7	3.3
4.9	1 to 2¼	21.0	18.0	15.0	12.0	8.9	5.9	3.0
5.3	1 to 2½	19.0	16.0	13.0	11.0	8.0	5.3	2.7
5.6	1 to 2¾	17.0	15.0	12.0	9.7	7.3	4.9	2.4
6.0	1 to 3	16.0	13.0	11.0	8.9	6.7	4.4	2.2
6.4	1 to 3¼	14.0	12.0	10.0	8.2	6.2	4.1	2.1
6.8	1 to 3½	13.0	11.0	9.5	7.6	5.7	3.8	1.9
7.5	1 to 4	12.0	10.0	8.3	6.7	5.0	3.3	1.7
8.3	1 to 4½	10.0	8.9	7.4	5.9	4.4	3.0	1.5
9.0	1 to 5	9.3	8.0	6.7	5.3	4.0	2.7	1.3
9.8	1 to 5½	8.5	7.3	6.1	4.9	3.6	2.4	1.2
10.5	1 to 6	7.8	6.7	5.6	4.4	3.3	2.2	1.1
11.2	1 to 6½	7.2	6.2	5.1	4.1	3.1	2.0	1.0
12.0	1 to 7	6.7	5.7	4.8	3.8	2.9	1.9	1.0
13.5	1 to 8	5.8	5.0	4.2	3.3	2.5	1.7	0.8
15.0	1 to 9	5.2	4.4	3.7	3.0	2.2	1.5	0.7
16.5	1 to 10	4.7	4.0	3.3	2.7	2.0	1.3	0.7
18.0	1 to 11	4.2	3.6	3.0	2.4	1.8	1.2	0.6
19.5	1 to 12	3.9	3.3	2.8	2.2	1.7	1.1	0.6
21.0	1 to 13	3.6	3.1	2.6	2.1	1.5	1.0	0.5
22.5	1 to 14	3.3	2.9	2.4	1.9	1.4	1.0	0.5
24.0	1 to 15	3.1	2.7	2.2	1.8	1.3	0.9	0.4
25.5	1 to 16	2.9	2.5	2.1	1.7	1.2	0.8	0.4
27.0	1 to 17	2.7	2.4	2.0	1.6	1.2	0.8	0.4
28.5	1 to 18	2.6	2.2	1.9	1.5	1.1	0.7	0.4
30.0	1 to 19	2.5	2.1	1.8	1.4	1.1	0.7	0.4
31.5	1 to 20	2.3	2.0	1.7	1.3	1.0	0.7	0.3

STANDARDIZING LIME-SULPHUR DIPPING BATHS FOR CATTLE.

Table showing quantity of concentrated dip to be added to each 100 gallons of bath to restore same to standard strength (2 per cent sulphid sulphur).

Per cent (on volume) of sulphid sulphur in concentrate.	Dilution figure of concentrate.	Per cent of sulphid sulphur in bath by test—									
		1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9
		Gallons of concentrated dip to be added to each 100 gallons of bath.									
6.0	1 to 2	25.0	22.0	20.0	17.0	15.0	12.0	10.0	7.5	5.0	2.5
6.5	1 to 2¼	22.0	20.0	18.0	16.0	13.0	11.0	8.5	6.7	4.4	2.2
7.0	1 to 2½	20.0	18.0	16.0	14.0	12.0	10.0	8.0	6.0	4.0	2.0
7.5	1 to 2¾	18.0	16.0	15.0	13.0	11.0	9.1	7.3	5.5	3.6	1.8
8.0	1 to 3	17.0	15.0	13.0	12.0	10.0	8.3	6.7	5.0	3.3	1.7
8.5	1 to 3¼	15.0	14.0	12.0	11.0	9.2	7.7	6.2	4.6	3.1	1.5
9.0	1 to 3½	14.0	13.0	11.0	10.0	8.6	7.1	5.7	4.3	2.9	1.4
10.0	1 to 4	13.0	11.0	10.0	8.8	7.5	6.3	5.0	3.8	2.5	1.3
11.0	1 to 4½	11.0	10.0	8.9	7.8	6.7	5.6	4.4	3.3	2.2	1.1
12.0	1 to 5	10.0	9.0	8.0	7.0	6.0	5.0	4.0	3.0	2.0	1.0
13.0	1 to 5½	9.1	8.2	7.3	6.4	5.5	4.5	3.6	2.7	1.8	0.9
14.0	1 to 6	8.3	7.5	6.7	5.8	5.0	4.2	3.3	2.5	1.7	0.8
15.0	1 to 6½	7.7	6.9	6.1	5.4	4.6	3.8	3.1	2.3	1.5	0.8
16.0	1 to 7	7.1	6.4	5.7	5.0	4.3	3.6	2.9	2.1	1.4	0.7
18.0	1 to 8	6.3	5.6	5.0	4.4	3.7	3.1	2.5	1.9	1.3	0.6
20.0	1 to 9	5.5	5.0	4.4	3.9	3.3	2.8	2.2	1.7	1.1	0.6
22.0	1 to 10	5.0	4.5	4.0	3.5	3.0	2.5	2.0	1.5	1.0	0.5
24.0	1 to 11	4.5	4.1	3.6	3.2	2.7	2.3	1.8	1.4	0.9	0.5
26.0	1 to 12	4.2	3.8	3.3	2.9	2.5	2.1	1.7	1.2	0.8	0.4
28.0	1 to 13	3.8	3.5	3.1	2.7	2.3	1.9	1.5	1.2	0.8	0.4
30.0	1 to 14	3.6	3.2	2.9	2.5	2.1	1.8	1.4	1.1	0.7	0.4
32.0	1 to 15	3.3	3.0	2.7	2.3	2.0	1.7	1.3	1.0	0.7	0.3
34.0	1 to 16	3.1	2.8	2.5	2.2	1.9	1.6	1.2	0.9	0.6	0.3

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(PROFESSIONAL PAPER.)

FIELD TEST WITH A TOXIC SOIL CONSTITUENT: VANILLIN.

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INTRODUCTION.

The presence of vanillin in soils and in a number of plants has led to a study of its effect on growth. Its harmful effect on wheat plants in water and nutrient culture solutions has been demonstrated, while the experiments reported in this paper deal with its effect in soils on crops grown in the field and in pots in the greenhouse.

Until recently vanillin had not been definitely isolated or identified in soils, but much information had been obtained in the work of this laboratory to indicate its presence in a number of soils. The isolation of vanillin in crystal form from certain soils and its definite identification has now been accomplished [1] and its effect on soil fertility has become an interesting subject for investigation.

Vanillin has been reported in the seeds and roots of oats,[2] seeds of white lupine,[3] asparagus shoots,[4] in raw-beet sugar,[5] and in the leaves and roots of a number of other plants. It has recently been reported to occur in rotten oak wood, in pineapples, in lawn grass, in ungerminated wheat, in wheat bran, in the roots, tops, and seeds of wheat seedlings, and in water in which wheat seedlings grew.[6] Its presence in wood and various forms of vegetation has led to the conclusion that vanillin in soils has its origin in vegetable débris.

Vanillin has the characteristics of an aldehyde, and, like the salicylic aldehyde already reported,[7] is toxic to plants, though to a less degree.

[1] Shorey, E. C., J. Agr. Res. **1,** 357 (1914).
[2] de Routon, Compt. rend., **125,** 797 (1897).
[3] Campani and Grimaldi, Chem. Centr., **1,** 377 (1888).
[4] Von Lippmann, Ber. Chem. Ges., **18,** 3335 (1885).
[5] Scheibler, Ber. Chem. Ges., **13,** 335 (1880) Lippmann, ibid., 662.
[6] Sullivan, M. X., Jour. Indus. and Eng. Chem., **6,** 119 (1914).
[7] Schreiner, O., and Skinner, J. J., Bul. 108, U. S. Department of Agriculture, 1914.

NOTE.—The effect upon plant growth of vanillin, a toxic soil constituent, as demonstrated in pot experiments and field tests, is described in this bulletin.

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It is harmful to wheat seedlings in water cultures, even in such low concentrations as a few parts per million, and the plants are killed in solutions of 500 parts per million in a few days.[1] The toxic effect is less marked upon the tops of the wheat plants than upon their roots. Vanillin is also harmful in nutrient culture solutions composed of calcium acid phosphate, sodium nitrate, and potassium sulphate. It is an oxidizable substance and is less harmful in solutions of some of these nutrient salts than in others, especially those high in nitrate.[2] Sodium nitrate and calcium carbonate,[3] which themselves induce oxidation, ameliorate the harmfulness of vanillin.

The isolation of vanillin from soils and its harmfulness to plants in aqueous solutions has made a study of its effect in soils and under field conditions essential. The results of such experiments with cowpeas, garden peas, and string beans will now be given, together with the action of vanillin on clover in soil in pots and with wheat plants grown in several soils of different characters.

EFFECT OF VANILLIN ON CLOVER IN POTS.

An experiment to determine the effect of vanillin on clover was made by growing clover in Chester loam soil in large pots. Ordinary clay flower pots holding 6 pounds of soil were used. One pot was untreated; the other had a total of 300 parts per million of the vanillin added to it.

When the soil was potted, 100 parts per million of the vanillin was added and clover then sown, 0.5 gram of seed per pot. The clover was sown April 12, and came up well. On April 28, 50 parts per million of vanillin were added in solution through a funnel passing into the soil nearly to the bottom of the pot, thus avoiding direct contact with the tops or roots of the clover. On May 15 another 50 parts per million were added, and on June 1 and June 10, 50 parts per million were added, making the total application 300 parts per million. The experiment was discontinued June 21, 1912. The effect of vanillin was noticeable from the first.

The harmful effect of the vanillin is shown by comparing the untreated pot and the vanillin-treated pot shown in Plate I. The vanillin-treated plants were healthy in appearance but stunted in growth.

The green weight taken at the termination of the experiment was 8 grams from the untreated pot and only 3.8 grams from the vanillin-treated pot, a decrease of 53 per cent.

The soil used in this experiment was a soil of moderate productiveness, and vanillin applied to it at different periods of the growth of the plants was distinctly harmful. Other experiments were made to

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[1] Schreiner, Reed, and Skinner, Bul. 47, Bureau of Soils, U. S. Dept. Agr. (1908).

[2] Schreiner and Skinner, Bul. 77, Bureau of Soils, U. S. Dept. Agr. (1911).

[3] Schreiner and Reed, Am. Chem. Soc., 30, 85 (1908).

test the effect of different amounts of vanillin in several soils, each having different properties and being of different geological origin. In the following experiments wheat was used as the test crop and the total application of vanillin was made before the soil was potted and seeds planted.

EFFECT OF VANILLIN ON WHEAT IN POTS.

In this experiment the effect of vanillin in several soils was studied by growing wheat in pots. The soils used were infertile Florida sand, an infertile sample of Susquehanna sandy loam, and a good sample of Hagerstown loam. The paraffined wire pot method [1] was used, six wheat plants were grown in each pot, and two pots were used for each treatment. The plants grew from May 5 to May 24. Photographs of the growing plants were taken, which show the action of vanillin in each soil. At the end of the experiment the green weight was determined.

The Florida sand used in this experiment had grown citrus fruits in the field and was unproductive. A laboratory examination showed the soil to be acid. Vanillin was isolated from this soil in the investigations referred to above. The Susquehanna sandy loam was taken from an infertile area in Maryland. The natural growth on this soil was poor, and its response to fertilizer and cultural treatments was only moderate. Its oxidizing power and life activities were found to be very weak. The Hagerstown loam is a fertile soil. The soil was taken from a productive field of the Pennsylvania Agricultural Experiment Station. The soil is neutral in reaction, has strong oxidizing power, and grows thrifty plants in pots.

Vanillin was used in amounts of 100 to 500 parts per million. It was applied to the soil by dissolving in water and mixing the solution in the soil before potting. The results of the experiment on the effect of vanillin in the Florida sand, Susquehanna sandy loam, and Hagerstown loam are given in Table I. The actual green weight of the plants grown in the two pots are given for each treatment and the relative weight with the growth in the untreated soil taken as 100.

TABLE I.—*Effect of vanillin on wheat plants in pots grown in Florida sand, Susquehanna sandy loam, and in Hagerstown loam.*

Treatment.	Florida yellow sand (infertile sand).		Susquehanna sand loam (unproductive soil).		Hagerstown loam (productive soil).	
	Green weight.	Relative weight.	Green weight.	Relative weight.	Green weight.	Relative weight.
	Grams.		*Grams.*		*Grams.*	
Soil untreated	1.40	100	1.80	100	1.98	100
Soil + 100 p. p. m. vanillin	1.32	94	1.85	103	1.87	94
Soil + 200 p. p. m. vanillin	1.32	94	1.70	94	2.02	102
Soil + 300 p. p. m. vanillin	1.35	98	1.33	74	2.05	103
Soil + 400 p. p. m. vanillin	1.20	86	1.30	72	1.96	99
Soil + 500 p. p. m. vanillin	1.18	84	1.02	57	1.95	99

[1] Cir. 18, Bureau of Soils.

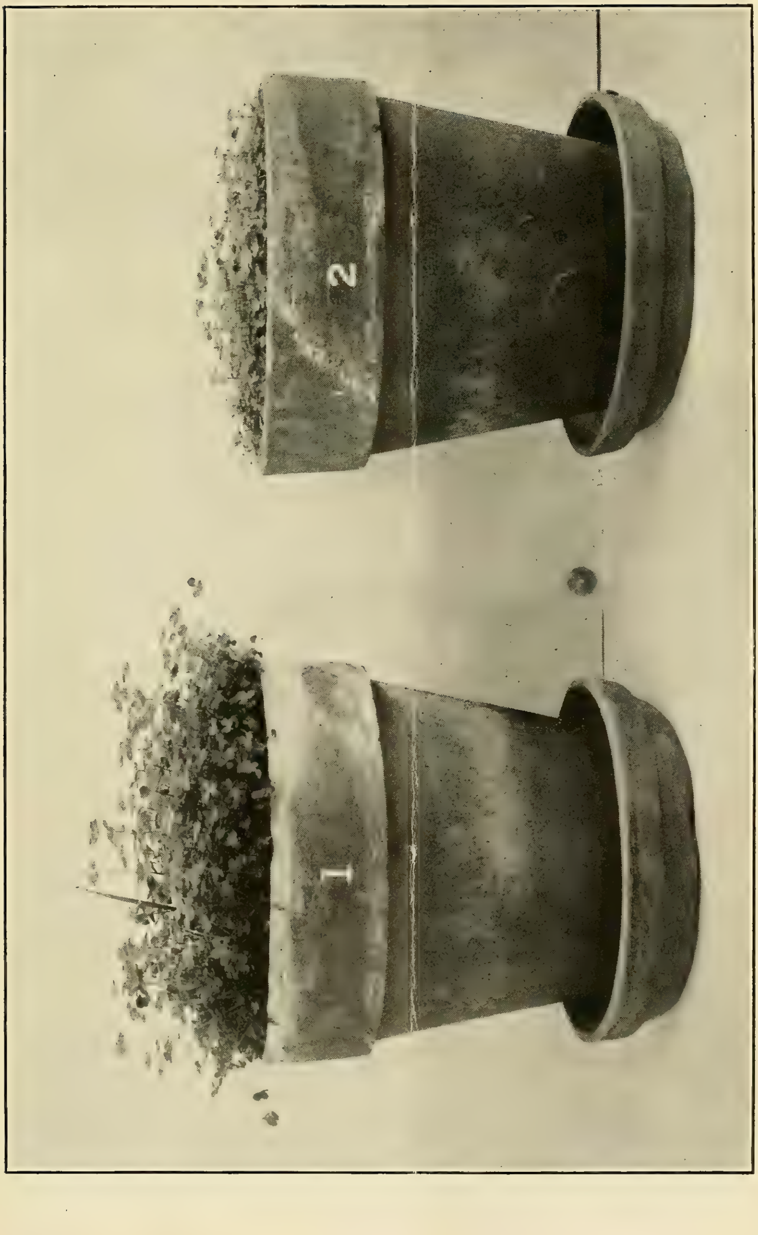
The vanillin was quite harmful in amounts of 400 and 500 parts per million in the Florida sand and was only moderately harmful in amounts of 100 to 300 parts per million. With the Susquehanna sandy loam the vanillin reduced growth considerably when applied at the rate of 300, 400, and 500 parts per million. It was slightly harmful with 100 and 200 parts per million. Vanillin had no harmful effect in the Hagerstown loam—two of the treatments were slightly above the check and three slightly below. The growth in the untreated soil of the Hagerstown loam was better than in the Susquehanna sandy loam and considerably better than in the Florida sand. The effect of vanillin in the three soils is shown in Plate II.

It is seen from this experiment that vanillin is harmful in two of the soils and has no effect in the third. Vanillin is easily oxidized and changed under favorable conditions, and if this took place the action on plant growth would not be noticeable. The Florida sand was found to contain vanillin when sent in from the field and, as would be expected, added quantities of vanillin would not be changed and it would remain as such to have its effect on plants grown in the soil. The Susquehanna sandy loam is also a soil having small oxidizing power and low life activity, and added quantities of vanillin apparently remained as such and had their effect on plant growth. The Hagerstown loam is a soil of entirely different characteristics, being highly productive, which indicates good life activities and good oxidizing power. Vanillin when added does not have harmful effects on plants grown in the soil, as it probably does not remain in this soil as such, but is changed or destroyed by the oxidation which is going on in soils of this character.

In order to study further the action of vanillin in soils and its bearing on soil fertility, the effect of vanillin under field conditions was tested in plots. Three leguminous crops—cowpeas, string beans, and garden peas—were grown to maturity in this experiment, with the following results:

EFFECT OF VANILLIN ON COWPEAS, STRING BEANS, AND GARDEN PEAS GROWN IN THE FIELD.

The effect of vanillin in soils under field conditions was tested on plots at the experiment farm of the Agricultural Department at Arlington, Va. Three crops were grown, namely, cowpeas, string beans, and garden peas. These experiments were made during the summer of 1913. The treated plot was adjoined on each side by an untreated plot growing the same crop. Each plot was $8\frac{1}{4}$ feet square, or one-fourth of a square rod; that is, one six hundred and fortieth of an acre.



EFFECT OF VANILLIN ON CLOVER.

(No, 1, untreated; No. 2, vanillin.)

FIG. 1.—EFFECT OF VANILLIN ON WHEAT IN FLORIDA SAND.

(No. 1, Soil untreated; No. 2, vanillin 100 p. p. m.; No. 3, vanillin 200 p. p. m.; No. 4, vanillin 300 p. p. m.; No. 5, vanillin 400 p. p. m.; No. 6, vanillin 500 p. p. m.)

FIG. 2.—EFFECT OF VANILLIN ON WHEAT IN SUSQUEHANNA SANDY LOAM.

(No. 1, Soil untreated: No. 2, vanillin 100 p. p. m.; No. 3, vanillin 200 p. p. m., No. 4, vanillin 300 p. p. m.; No. 5, vanillin 100 p. p. m.; No. 6 vanillin 500 p. p. m.)

FIG. 3.—EFFECT OF VANILLIN ON WHEAT IN HAGERSTOWN LOAM.

(No. 1, Soil untreated; No. 2, vanillin 100 p. p. m.; No. 3, vanillin 200 p. p. m.; No. 4, vanillin 300 p. p. m.; No. 5, vanillin 400 p. p. m.; No. 6, vanillin 500 p. p. m.)

FIG. 1.—EFFECT OF VANILLIN ON COWPEAS IN THE FIELD.

FIG. 2.—EFFECT OF VANILLIN ON GARDEN PEAS IN THE FIELD.

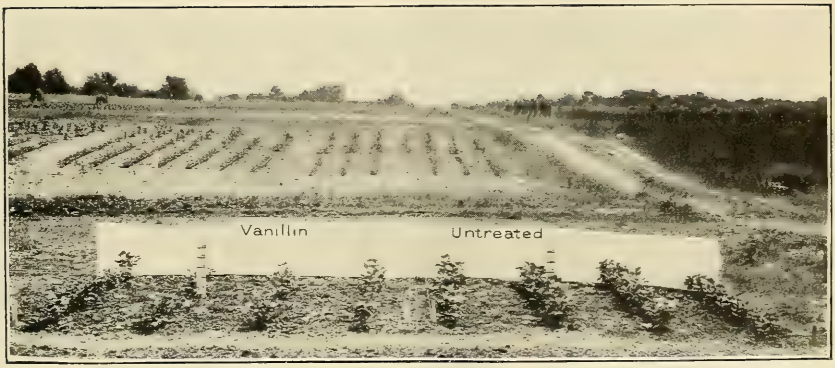


FIG. 3.—EFFECT OF VANILLIN ON STRING BEANS IN THE FIELD.

FIG. 1.—YIELD OF COWPEAS, VINES, AND PODS ON CHECK PLOT *a* AND ON VANILLIN-TREATED PLOT.

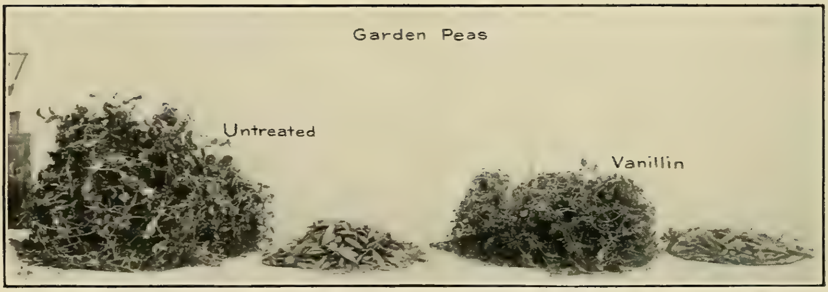


FIG. 2.—YIELD OF GARDEN PEAS, VINES, AND PODS ON CHECK PLOT *a* AND ON VANILLIN-TREATED PLOT.

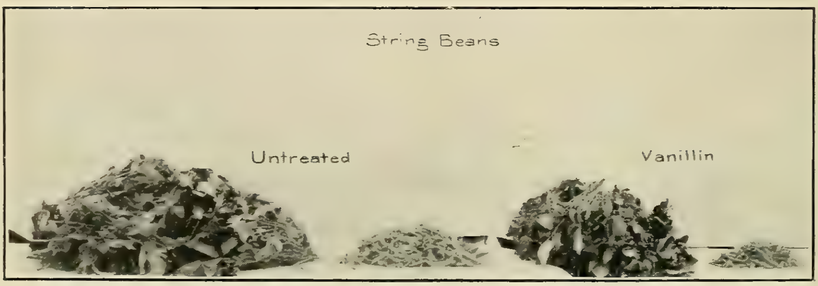


FIG. 3.—YIELD OF STRING BEANS, VINES, AND PODS ON CHECK PLOT *a* AND ON VANILLIN-TREATED PLOT.

The soil on which these experiments were made is a silty clay loam, low in organic matter. The ground is level and has surface drainage. The soil throughout these plots and their controls is uniform, so the results secured should not be considered as unduly influenced by irregularities due to nonuniformity of the soil in different plots. The soil is of an acid nature. The land was plowed early in May and prepared for seeding.

Four applications of vanillin were made. The first on May 20, one day before the planting of seed. The other three applications were made periodically during the growth of the crops—May 28, June 5, and June 24. The vanillin was applied by dissolving in water, sprinkling the solution uniformly on the surface of the ground before planting, and raking the soil thoroughly. The remaining applications were made after planting by sprinkling the solution between the rows of plants, the soil being subsequently cultivated. The total application was at the rate of 285 pounds per acre, in four equal parts.

The crops germinated uniformly. The effect of the vanillin was noticeable from the beginning and throughout the experiment. The growth was stunted, though the plants grew slowly to maturity, and were harvested.

EFFECT OF VANILLIN ON COWPEAS.

The cowpeas were sown May 21, 1913, the plots having been previously prepared, and were harvested September 7, 1913. The plants in the untreated plots made more vigorous growth and had a better color than those in the vanillin-treated plot. The vanillin-treated plants had a pale-green color and grew slenderer than those on the untreated plot. The appearance of the plants on June 27 is shown in Plate III, figure 1. The four rows of plants growing on the left are on the vanillin-treated plot, and the four rows on the right on the untreated plot. The picture shows that at this stage of growth the vanillin has greatly affected the cowpeas. This effect was even more marked as the crop approached maturity. When mature the peas were picked from the vines and weighed. The weight of the cowpea vines was taken, and after drying the weight of the cured hay was also determined. In Plate IV, figure 1, are shown the vines and pods as taken from the untreated and treated plots. The effect of the vanillin in depressing yield is here also apparent.

In Table II are given the yields obtained in this experiment with vanillin and cowpeas. The weight of vines and pods is given as obtained from the individual plots and also in terms per acre.

TABLE II.—*Yield of cowpeas as affected by vanillin in the field.*

Treatment.	Yield per plot.			Yield per acre.		
	Vines.		Pods.	Vines.		Pods.
	Green.	Cured.		Green.	Cured.	
	Pounds.	*Pounds.*	*Pounds.*	*Tons.*	*Tons.*	*Tons.*
Check *a*	28.0	10.0	6.6	8.96	3.20	2.11
Check *b*	23.0	8.5	5.6	7.36	2.72	1.79
Average check	25.5	9.3	6.1	8.16	2.96	1.95
Vanillin	17.0	5.7	4.0	5.44	1.82	1.27
Difference	8.5	3.6	2.1	2.72	1.14	.68

From the table it is seen that the average production of the two check plots was 8.16 tons per acre of green pea vines, or 2.96 tons per acre of cured hay, while the vanillin plot produced only 5.44 tons per acre of green vines, or 1.82 tons per acre of cured hay. This is a reduction of 2.72 tons per acre of green vines, or 1.14 tons per acre of cured hay due to the vanillin, a reduction of 33 per cent of green vines and 39 per cent of cured hay. The average production of the two check plots was 1.95 tons per acre of pods, while the vanillin plots produced 1.27 tons per acre, a reduction of 35 per cent.

EFFECT OF VANILLIN ON GARDEN PEAS.

The garden peas were sown in the untreated and vanillin-treated plots May 21, the germination was good, and a good stand was obtained. The vanillin checked the growth of the peas from the start and the difference was pronounced throughout the entire period of growth. The crop was harvested June 30; the vines and peas were weighed separately. The appearance of the plants in the early stages of their growth is shown in Plate III, figure 2. The weights and measurements of vines and peas are given in Table III.

TABLE III.—*Yield of garden peas as affected by vanillin in the field.*

Treatment.	Yield per plot.			Yield per acre.		
	Vines.	Peas.		Vines.	Peas.	
	Pounds.	*Pounds.*	*Pints.*	*Pounds.*	*Pounds.*	*Pecks.*
Check *a*	1.72	1.66	4.50	1,101	1,062	180
Check *b*	1.50	1.48	4.0	950	947	160
Average check	1.61	1.57	4.25	1,030	1,004	170
Vanillin	1.12	1.14	3.00	717	730	120
Difference	.49	.43	1.25	313	274	50

As seen from the table, the yield of the vanillin plot is far below the check plots. The average production of the two untreated plots was 1,030 pounds per acre of vines and 170 pecks of peas per acre,

while the vanillin plot produced 717 pounds per acre of vines and 120 pecks of peas. This is a reduction of 30 per cent in vines and 20 per cent in marketable peas, due to the presence of vanillin.

Plate IV, figure 2, shows the harvested crop grown in the untreated plot and in the vanillin plot.

EFFECT OF VANILLIN ON STRING BEANS.

String beans were also affected by vanillin. The beans were sown May 21, 1913; they germinated well and came up uniformly. The plants in the untreated plot grew better and were more thrifty than those in the vanillin plot. Plate III, figure 3, shows the comparative growth in the early stage, and from this it is seen that the untreated plants are much larger. The crop was harvested July 22. The beans were picked from the vines and measured. The results are given in Table IV.

TABLE IV.—*Yield of string beans as affected by vanillin in the field.*

Treatment.	Yield per plot.			Yield per acre.		
	Vines.	Beans.		Vines.	Beans.	
	Pounds.	*Pounds.*	*Pints.*	*Pounds.*	*Pounds.*	*Pecks.*
Check *a*	3.55	1.90	4.75	2,272	1,236	190
Check *b*	2.94	1.66	4.15	1,882	1,062	166
Average check	3.24	1.78	4.45	2,070	1,149	178
Vanillin	2.71	.55	1.50	1,734	352	56
Difference	.53	1.23	2.95	336	797	122

The average yield for the check plots was 2,070 pounds of vines per acre and 178 pecks of beans per acre. The yield of the vanillin plot was 1,734 pounds of vines per acre and 56 pecks of beans per acre. This is a decrease of 336 pounds of vines per acre and 122 pecks of beans per acre. The harvested crop from the untreated plot and the vanillin plot is shown in Plate IV, figure 3.

PRESENCE OF VANILLIN AND ITS EFFECT IN THE SOIL SIX MONTHS AFTER APPLICATION.

The question of the length of time the vanillin would persist in the Arlington soil and have an influence on its crop-producing power has also been investigated by a chemical study in the laboratory and by pot tests. Samples of soil for these purposes were obtained from the plots the last of November, six months after the substance was applied, and after a crop had been matured. The soils were examined for vanillin by the method already described by Shorey.[1] The method, in brief, consists of making an alkaline extract of the soil. The extract is acidified and filtered and then shaken out with ether.

[1] J. Agr. Research, 1, 357 (1914).

The ether extract is shaken with a strong solution of sodium bisulphite, which treatment removes from the ether compounds of an aldehyde nature. After separating the bisulphite from the ether it is acidified with enough sulphuric acid completely to decompose it, is freed from sulphur dioxide by blowing air through it, and is again shaken with ether. The ether extract obtained by this process on evaporation gave an oily residue. The residues secured from the soils taken from the vanillin-treated plots which had grown cowpeas, garden peas, and string beans had the odor of vanillin. The residues were purified according to the method given in the paper cited. An aqueous solution of the purified residue from the three soils smelled strongly of vanillin. The aqueous solutions gave the color reactions characteristic of vanillin. Ferric chloride added to a portion of the solution gave a blue-violet color. When boiled with resorcinol and hydrochloric acid a red color resulted. The solution gave a violet color with a mixture of sulphuric and hydrochloric acid and acetone water. Bromine water and ferrous sulphate gave a green color. On the addition of the reagent of Folin and Denis, the solution having been made alkaline with sodium carbonate, a clear blue color developed.

As is shown from the above examination that this vanillin-treated field soil still contained the substance, it was tested in pots as to its qualities for growing plants.

In this experiment wheat was grown in the greenhouse in paraffined wire pots, using the respective soils from the vanillin-treated plot and the check plots which in the field had grown cowpeas, garden peas, and string beans. The plants grew from December 11, 1913, to January 6, 1914. Two pots with 6 plants each were used for each soil. The results of the experiment are given in Table V.

TABLE V.—*Growth of wheat in pots of soil taken from the field plots six months after treatment with vanillin.*

Plot.	Green weight of wheat plants on—		
	Soil from plots untreated.	Soil from vanillin plots.	Relative growth, check = 100.
	Grams.	*Grams.*	
Cowpea plot	1.48	1.09	74
Garden pea plot	1.47	1.10	75
String bean plot	1.54	1.10	71

The table shows that the soils from the vanillin-treated plots were harmful to wheat in soil collected six months after the vanillin had been applied.

A similar experiment was made with these soils, except that the crops grown in the pots were identical with those which had grown in

the field the preceding season; that is, cowpeas on the cowpea soil from the check plot and from the vanillin plot, string beans on the string bean soil from both check and treated plots, garden peas on the garden pea soil from both check and treated plots. Two pots were used in each case and two plants in each pot. The plants grew from December 11 to January 6. The vegetative growth made in this experiment is given in Table VI.

TABLE VI.—*Growth of cowpeas in pots of soil from cowpea field plot; garden peas in soil from garden pea field plot; string beans in soil from string bean field plot; collected six months after treatment with vanillin.*

Plot.	Green weight of plants upon—		Relative growth, check=100.
	Soil from plots untreated.	Soil from vanillin plots.	
	Grams.	*Grams.*	
Cowpeas plot	4.30	3.05	71
Garden peas plot	5.60	4.00	71
String beans plot	7.80	7.35	94

The figures in the table show that vanillin was still harmful to the respective crops six months after the application of vanillin, and after it had produced the same crop in the field. These experiments show that vanillin persists in this heavy silty clay loam soil and affects its fertility for a considerable length of time.

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BULLETIN OF THE
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No. 165

Contribution from the Bureau of Entomology, L. O, Howard, Chief.
December 31, 1914.

(PROFESSIONAL PAPER.)

QUASSIIN AS A CONTACT INSECTICIDE.

By William B. Parker,
Entomological Assistant, Bureau of Entomology.[1]

INTRODUCTION.

Quassia chips, the active principle of which is quassiin, have been employed for many years in the preparation of spray solutions for the control of the hop aphis (*Phorodon humuli* Schr.). Several formulas have been followed, and there are several methods of preparation according to these formulas. Several factors have brought about the variations in the formulas, (1) instability in the percentage of quassiin in the chips, (2) the total amount of available quassiin in the chips probably not extracted, due to the method of preparation, and (3) the fact that there appeared to be no fundamental data accumulated on this subject. The writer accordingly commenced the investigation, which has been taken up from an insecticidal standpoint, and any chemistry that is mentioned other than very simple matters is taken from the various sources. Acknowledgments are due to Prof. George P. Grey, of Berkeley, Cal., and Mr. G. H. P. Leichthardt, of Sacramento, Cal., for valuable suggestions, and to Mr. R. E. Campbell, of the Bureau of Entomology, who ably assisted the writer in determining the efficiency of the several formulas.

During the investigation of the life history and control of the hop aphis[2] it was observed that there were several formulas for the use of quassia chips. These all appeared to give satisfactory results when carefully prepared and applied, but it will be observed from the following formulas that if the weaker one killed the aphides, the use of the stronger one resulted in a waste of material and extra expense.

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[1] Resigned August 31, 1914.

[2] Parker, Wm. B., The Hop Aphis in the Pacific Region. U. S. Dept. Agr., Bur. Ent. Bul. 111, 39 p., 8 fig., 10 pl., May 6, 1913.

NOTE.—The results of an investigation to determine the most suitable solution of quassiin for use as a spray for the control of the hop aphis are discussed in this bulletin.

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The following formulas are typical examples of the variation in the amount of ingredients and the cost per 100 gallons:

	No. 1.	No. 2.	No. 3.
Quassia chips ... pounds..	2.8	8	9
Whale-oil soap ... do....	1.6	6	6
Water ... gallons..	100	100	100
Cost per 100 gallons ... cents..	31	69	74.2

These formulas are concocted differently by different growers. Some soak the chips 24 hours in a barrel of water and then boil them for 2 hours. Some boil them for 2 hours without previous soaking, and others boil them with the whale-oil soap. The several formulas and methods of preparation all have their advocates among the hop growers.

CHEMICAL LITERATURE ON QUASSIIN.

The quassia chips commonly used in preparing spray solutions are the wood of the Jamaica quassia (*Picrasma excelsa* Swz.). The literature on the chemical nature of quassiin, the active principle of quassia wood, was found to be very limited, but the few important references that the writer was able to obtain are discussed below.

The wood of *Picrasma excelsa* (Swz.) Planch. (*Quassia e* Swz.; *Q. polygama* Lindsay; *Piceaena e* Lindl.; *Simaruba e* D. C.) or of *Quassia amara* L. (Fam. Simarubaceæ).

Description.—Jamaica quassia. Occurring in various forms, usually chips, raspings, or billets, yellowish white or pale yellow, and of rather coarse texture; odor slight; taste intensely bitter; medullary rays containing tetragonal prisms or small, arrow-shaped crystals of calcium oxylate. Billets of Jamaica quassia are usually 12.5 cm. or more in diameter; in tangential section the medullary rays are mostly 3 to 5 rows of cells in width.

Surinam quassia. Occurring usually in billets not exceeding 7.5 cm. in diameter; the wood is heavier, harder, and more deeply colored than that of Jamaica quassia, and the medullary rays in tangential section are mostly 1 or 2 rows of cells in width.

Constituents.—Although Jamaica quassia is said to contain traces of a yellowish alkaloid, giving a fine blue fluorescence with acidulated alcohol, the important bitter principle is a neutral, crystalline substance, commonly known as quassiin, but determined by Massute to be a mixture of two crystalline bodies, which he denominated α– and β– picrasmin.

Quassiin is extracted by neutralizing the aqueous infusion with soda, precipitating with tannin and decomposing the precipitate with lead oxide or lime. It is commonly said to exist to the extent of only 0.05 to 0.15 per cent, but really exists in much larger amount, Wiggers says 0.75 per cent. This discrepancy is probably due to the fact that it is difficult to procure in the pure state, and that the purification processes involve considerable loss. Quassiin crystallizes in needles or prisms, and is soluble in alcohol and in chloroform and in 1,200 parts of cold water. Its bitterness is most intense. The α–picrasmin ($C_{35}H_{46}O_{10}$) melts at 204° C. The β–picrasmin ($C_{36}H_{48}O_{10}$) at 209° to 212° C. (408.2°–413.6° F.). The bitter principle of Surinam quassia is closely related and of similar action, but not identical.[1] To it the name *quassin* is commonly applied.

[1] Hare, H. A., Caspari, C., and Rusby, H. H. National Standard Dispensatory, ed. 2, revised and enlarged, p. 1334, Philadelphia, 1909.

Quassine, the active principle of *Quassia amara*, is amorphous or crystalline. It has been isolated by Winkler. It is colorless, inodorous, opaque, and inalterable in the air, slightly soluble in water, much more soluble in water charged with salt or organic acids, and in alcohol.

Action on plants: Plants are not injured by spraying with aqueous extracts of quassia.[1]

Quassia.—Constit.: Wood: Picrasmin, $C_{35}H_{46}O_{10}$: quassin, $C_{10}H_{12}O_3$ (or, $C_{32}H_{42}O_{10}$ [?]); quassol, $C_{40}H_{70}O—H_2O$; alkaloid; resin; mucilage; pectin.—Bark: Quassin; alkaloid; resin; pectin. (*Quassia amara* contains 4 bitter principles; *Picræna excelsa* contains only 2): quassol,—[2]

"Quassiin ($C_{32}H_{42}O_{10}$) may be obtained in a fairly pure state by exhausting quassia-wood with hot water, precipitating the solution with neutral lead acetate, removing the excess of lead from the filtrate by sulphuretted hydrogen and shaking the filtered liquid with chloroform. On evaporation, the quassiin is obtained nearly colorless, and, with some difficulty, in a distinctly crystalline condition. Quassiin has an intensely and very persistent bitter taste. It is sparingly soluble in cold water, more readily in hot water, and is easily soluble in alcohol. Its best solvent is chloroform, which extracts quassiin readily from acidulated solutions.

An aqueous solution of quassiin does not reduce Fehling's solution or an ammonio-nitrate of silver. The solid substance gives no coloration (or merely yellow) when treated with strong sulphuric acid, or with nitric acid 1–25 sp. gr.; nor is any color produced on warming. * * *

A solution of quassiin gives a white precipitate with tannin. The reaction is used by Christensen, Oliveri, and others, to isolate quassiin from its solutions, and by Enders to separate it from picrotoxin. In the author's hands the reaction has not proved satisfactory. The liquid is very difficult to filter, and the filtrate still retains an intensely bitter taste, showing that the precipitation is very incomplete. As an analytical method the reaction is useless, but it is of some value as a qualitative test. The test must be made in cold solution. Possibly a more complete precipitation of quassiin by tannic acid might be effected in an alcoholic solution.

Quassiin gives a brown coloration with ferric chloride. The reaction is best observed by moistening a quassiin residue in porcelain with a few drops of a weak alcoholic solution of ferric chloride, and applying a gentle heat. A fine mahogany-brown coloration is produced." [3]

The quassiin used in the following experiments was extracted according to directions given by Allen.[4] It was further found that when boiled in alcohol a precipitate formed. This was filtered off, the filtrate evaporated to dryness over a water bath, and the resulting dark resinous material extracted with boiling water. When extraction was complete a dark brown crusty material remained. The resulting extract was light yellow and perfectly clear. It was found to be intensely bitter.

When cool this aqueous solution was extracted with chloroform, evaporated over a water bath, and weighed and made into a percentage solution.

[1] Bourcart, E., Insecticides, Fungicides and Weedkillers, p. 376. London, 1913.

[2] Merkes 1907 Index, ed. 3, p. 366. New York, 1907.

[3] Allen, A. H., Commercial Organic Analysis, ed. 2 revised and enlarged, v. 3, pt. 3, p. 187–188, Philadelphia, 1896.

[4] Except the solution was not acidulated before extraction with acid.

In studying the use of quassiin as a contact insecticide it became desirable to determine in what solvents and solutions this compound was soluble. Table I gives the results of the experiments which were carried out with this purpose in view.

TABLE I.—*Results of solubility tests for quassiin.*

No.	Material.	Action.
1	Chloroform	Readily soluble.
2	Ether	Not soluble.
3	Methyl alcohol	Readily soluble.
4	Ethyl alcohol	Do.
5	Hot water	Do.
6	Cold water	Sparingly soluble 1–1,200.
7	Kerosene	Not soluble.
8	Gasoline	Do.
9	Carbon tetrachlorid	Do.
10	Benzine	Do.
11	Turpentine	Possibly soluble.
	RESULTS OF TESTS WITH SOLUTIONS.	
12	Potassium hydroxid	Readily soluble, solution yellow.
13	Sodium hydroxid	Do.
14	Calcium hydroxid	Do.
15	Potassium cyanid	Do.
16	Sodium carbonate	Do.
17	Hydrocyanic acid	Do.
18	Ammonium hydrate	Do.
19	Whale-oil soap (alkaline)	Do.
20	Sodium chlorid	Apparently insoluble.
21	Hydrochloric acid	Do.
22	Sulphuric acid	Do.
23	Nitric acid	Do.
24	Acetic acid	Do.

The foregoing table represents the results of experiments which were conducted with quassiin in an attempt to determine some cheap solvent or solution, other than hot water, by which it could be extracted from the wood.

EXTRACTION OF QUASSIIN FROM SOLUTIONS.

It was found that when the solutions of potassium hydroxid, sodium hydroxid, sodium carbonate, etc., with quassiin, were acidulated with sulphuric acid, the quassiin could be readily removed in chloroform. This process would apply when testing the percentage of quassiin in such solutions.

DETERMINATION OF PURITY OF QUASSIIN USED.

Since the purity of the quassiin used in spraying experiments is an important factor in figuring proportions, an attempt was made to determine the amounts of material other than quassiin which might be present in the stock solution.

Following a suggestion in Allen, tannin was added to an aqueous solution of quassiin taken from the stock solution. A fine precipitate appeared, but unfortunately it passed through an ordinary filter paper.

It being observed that tannin is not extracted from an aqueous solution by chloroform, an attempt was made to collect the chloroform-soluble material which was not precipitated by the tannin. The solution was accordingly shaken with chloroform, and the chloroform separated in a separating funnel. When replaced in aqueous solu-

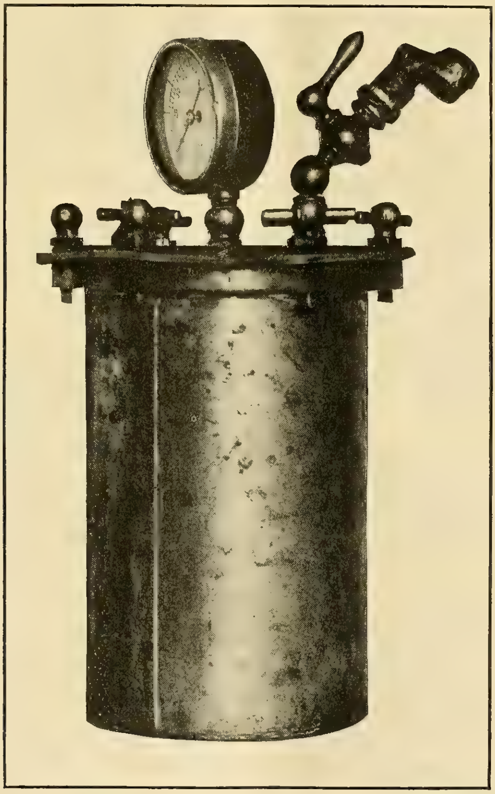

FIG. 1.—Compressed-air spray machine used in applying quassiin solution. (Original.)

tion, the extracted material was found to be intensely bitter and gave all the appearance of being quassiin. It is evident that all of the quassiin is not precipitated by tannin.

Because the material used proved effective as an insecticide at dilutions of 0.4 grams to 1,500, 1,800, and 2,000 cubic centimeters, the writer believes that it was comparatively pure quassiin.

INSECTICIDAL VALUE OF QUASSIIN.

The determination of the insecticidal value of quassiin is the main object of this investigation. In accomplishing this object an attempt is made to compare the action of quassiin to the action of a standard contact insecticide. Nicotine sulphate is taken as the standard,

and in these experiments is used at the rate of 1–2,000. The nicotine sulphate used was standardized to 40 per cent and the solution of quassiin was used so that it would correspond with the 40 per cent solution of nicotine sulphate. For instance, instead of using 1 gram of quassiin to 2,000 cubic centimeters of water, 0.4 gram was used to 2,000 cubic centimeters of water.

During the early part of the work it was discovered that the whale-oil soap, even when used at the greatest dilution at which it had any spreading effect (1 pound to 100 gallons), killed a certain percentage of the aphides. Since a spreader is necessary, experiments were inaugurated to find one that would have no effect upon the insects treated. It was found that the soap bark solution which was being used in some other work was an excellent spreader and did not affect the insects in the least. In all of the following experiments a water decoction of this material was used at the rate of 2 pounds of soap bark to 100 gallons of water.

In applying the solutions, a compressed-air spray machine (fig. 1) which maintained 50 pounds pressure and handled as small an amount as 200 cubic centimeters was used. A fine mist nozzle was so adjusted to this pressure of 50 pounds that a washing rather than a mist spray was produced.

In conducting the experiments detailed in Table II prune twigs infested by the hop aphis (*Phorodon humuli* Schrank) and the prune aphis (*Hyalopterus pruni* Fab.) were brought from the field and, after being sprayed with the solutions, were set in moist sand. By placing the pots of sand containing the sprayed twigs on sheets of paper the percentage of the insects that were killed by the solutions were readily obtained. Check twigs were kept to make sure that there was not a marked mortality from some other cause.

Table II gives the results of the spraying experiments with quassiin in aqueous solution and also in solutions of certain alkaline substances.

TABLE II.—*Results of experiments with quassiin as a contact insecticide.*

SERIES NO. 1. WITH SOAP BARK IN LABORATORY.

Formula.	Number of aphides sprayed.	Per cent of aphides killed.
0.4 grams to 3,000 cc.	904	85.1
0.4 grams to 2,000 cc.	8,060	93.02
0.4 grams to 1,800 cc.	1,119	94.6
0.4 grams to 1,500 cc.	1,310	93.9
0.4 grams to 1,000 cc.	1,831	99.7

SERIES NO. 2. WITH WHALE-OIL SOAP IN FIELD.

Formula.	Number of aphides sprayed.	Per cent of aphides killed.
0.4 grams to 2,000 cc.	1,776	99.4
0.4 grams to 1,800 cc.	3,197	99.8
0.4 grams to 1,500 cc.	3,546	99.8

TABLE II.—*Results of experiments with quassiin as a contact insecticide*—Continued.

SERIES NO. 3. WITH SOAP BARK ON PRUNE APHIS IN FIELD.

Formula.	Number of aphides sprayed.	Per cent of aphides killed.
0.4 grams to 2,000 cc	1,923	97.5
0.4 grams to 1,800 cc	721	99.2
CHECK SERIES.		
Whale-oil soap, 3 pounds to 100 gallons	1,030	[1 2] 84.6
Soap bark, 2 pounds to 100 gallons	1,202	[1] 21
Nicotine sulphate, 0.4 grams to 2,000 cc., with soap bark, 2 pounds to 100 gallons	930	96.9

[1] These were the largest percentages obtained for the check materials.
[2] In field.

From the foregoing table it will be readily seen that quassiin used at the rate of 0.4 grams to 2,000 cubic centimeters, or 6½ ounces of 40 per cent solution to 100 gallons, was almost as effective against the hop aphis and the prune aphis as nicotine sulphate, 0.4 grams to 2,000 cubic centimeters, or 6½ ounces to 100 gallons. The difference is approximately 3 per cent, while quassiin, 0.4 grams to 1,000 cubic centimeters, is fully as effective.

The writer has not so far tested this material upon insects other than those mentioned, but believes that it will prove effective elsewhere if used in proportions corresponding to the amounts of nicotine sulphate that are known to be effective.

CONCLUSION.

Picrasma excelsa Swz. (quassia wood) is a native of Jamaica, and, according to data obtained, is available in considerable quantities.

The percentage of quassiin in the quassia wood varies somewhat, and does not appear to be definitely known. Supposing it to be 0.75 per cent, as given by one author, to use the quassiin at an effective rate of 0.4 grams to 2,000 cubic centimeters, it would take only 1½ pounds of the chips to 100 gallons of spray. To be on the safe side, double the amount of chips calculated to be necessary, and we have the following formula [1] and cost per 100 gallons of spray:

Quassia chips, 0.75 per cent quassiin, 3 pounds, at $0.04	$0.12
Whale-oil soap, 3 pounds, at $0.04	.12
Total cost of materials per 100 gallons	.24

Quassiin can be readily extracted from quassia wood, *Picrasma excelsa* Swz., in a comparatively pure form. (See p. 3.) It probably could be more cheaply extracted in an impure water-soluble form by using sodium carbonate solution. The percentage of quassiin could be determined and the material evaporated until a standardized solution was made. Such a material could be diluted and used with

[1] This formula corresponds very closely to formula No. 1, page 2.

whale-oil soap, or some other spreader, as in the case of nicotine sulphate. The writer believes that quassiin has possibilities as a commercial insecticide and that it could be cheaply prepared and possibly sold at a lower price than some of the materials that are now on the market.

The foregoing data were obtained under conditions existing at Sacramento, Cal., and may not hold for a more humid climate. The efficiency of the quassiin should be determined for some other locality before a commercial recommendation is made.

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BULLETIN OF THE U.S. DEPARTMENT OF AGRICULTURE

No. 166

Contribution from the Bureau of Animal Industry, A. D. Melvin, Chief.
January 22, 1915.

(PROFESSIONAL PAPER.)

OPHTHALMIC MALLEIN FOR THE DIAGNOSIS OF GLANDERS.

By JOHN R. MOHLER, *Assistant Chief of Bureau*, and ADOLPH EICHHORN, *Senior Bacteriologist, Pathological Division.*

INTRODUCTION.

It is no longer doubted that in the work of controlling glanders the destruction of the infected animals should be given prompt consideration, and, if possible, the infection should be traced to its origin. Unfortunately, the nature of the disease is such that only a comparatively small proportion of the cases can be recognized by the ordinary clinical examination, and as long as we limit our efforts to the destruction of these cases the disease will continue to spread. An effective control can be accomplished only by the elimination of all centers of infection of glanders. Therefore it is essential primarily to have a means of diagnosing accurately all forms of the disease.

Numerous publications have been issued on the various methods of diagnosis, and it seems that while some favor a certain method or methods, others appear to produce sufficient evidence to point out the inadequacy of these methods. There is no question that in the last decade important progress has been made in the diagnosis of this disease. Since the discovery of mallein, competent investigators have fruitfully studied this phase of the question of the control of glanders, and at the present time we possess several methods by which we are reasonably sure of diagnosing practically all cases of glanders. A minimum percentage of failures will probably always have to be contended with, as a good many factors enter into the execution of any test.

In judging a method which would be the most satisfactory for the diagnosis of glanders various things have to be taken into considera-

NOTE.—This bulletin points out the advantageous and satisfactory use of the ophthalmic mallein test in the diagnosis of glanders and the necessity for prompt action on reactors to this test in eradicating this disease. Of interest to veterinarians and State live-stock sanitary authorities.

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tion, but especially the reliability of the test. It should be convenient, the results should be manifested as early as possible, the reaction should be distinct and well marked, and, probably the most important of all, it should be possible for the practicing veterinarian to apply the test. The last condition must be seriously considered, since the standing of the veterinarian in the community and the confidence of the public in his work would be more manifest if in suspected cases he could personally decide on the diagnosis instead of having to depend entirely on the results of serum tests made at some distant laboratory.

VARIOUS METHODS FOR DIAGNOSING GLANDERS.

It would require a great amount of space to enter into the history of the various methods of diagnosis and to enumerate the data we possess on the different tests. The advantages and disadvantages of the various methods, especially of the subcutaneous mallein tests, have been repeatedly published and are accessible to all those who are interested in the subject. There is no question that the subcutaneous mallein test is one of the valuable diagnostic agents for glanders, but no one can any longer deny that failures from this test are more numerous than are desirable. As a matter of fact, the uncertainty of the results from this test caused numerous investigators to seek some other method which might replace the subcutaneous mallein test. Besides the failures resulting from it, the technic of executing the test, together with the time required for its determination, make it unpopular with many veterinarians and sanitary officers.

Of the other tests which from time to time have been devised for the diagnosis of glanders, the precipitation, the opsonic, and the conglutination tests will not be considered, since the results obtained from them are not encouraging.

For laboratory tests the combined agglutination and complement-fixation test will no doubt remain the most satisfactory, and should always be applied in cases where doubt arises as to the results of other tests carried out by the practicing veterinarian. These latter should be considered as accessory tests and provision should be made everywhere so that in case of doubt the serum could be subjected to the laboratory test mentioned, and the final decision should rest on its outcome.

THE OPHTHALMIC MALLEIN TEST.

During the last few years the ophthalmic mallein test has gained great favor in the diagnosis of glanders. The popularity of the test is rapidly gaining wherever it has been applied, and among its supporters we find at the present time the greatest authorities on the

subject of glanders and on clinical diagnosis. This method of testing is at present officially recognized in Austria, and the indications are that ere long it will constitute the official test in other countries. The results obtained in Austria, where the test has been employed for several years, are very gratifying, and Prof. Schnurer, of that country, one of our greatest authorities on glanders, claims that the control of the disease can be very satisfactorily carried out by the application of the eye test, supplemented in doubtful cases by the agglutination test. Bavaria has recently adopted this method of diagnosis for official testing. In Germany the method is also gaining in favor, and current veterinary literature contains expressions of satisfaction with this test from many German authorities. In the United States the Bureau of Animal Industry, in consideration of the favorable results obtained, has recognized this method of diagnosis for interstate shipments of equines. The test has also been officially recognized by the Canadian authorities, and thus far no sanitary official connected with any of the States in this country has declined to approve this test.

The favorable results which have been obtained with this diagnostic method can no longer be denied. Its practicability is apparent, and its use in the control of glanders appears to be now an absolute necessity.

SIMPLICITY OF PROCEDURE.

The ophthalmic test has a great advantage over others because of its very simple application. It may be readily executed by any veterinarian, and its other advantages are that the results are obtained in a comparatively short time and are, as a rule, distinct and definite. The simplicity of its application is plainly manifest when compared to the subcutaneous test, as it is only necessary to drop two to three drops of concentrated mallein into one of the eyes of the animal to be tested, or, by a still simpler procedure, to dip a camel's-hair brush into mallein and introduce this into the conjunctival sac of the animal. The reaction usually commences in five to six hours after the introduction of the mallein and lasts from 24 to 36 hours. A positive reaction is manifested by a purulent secretion from the tested eye. This may be very profuse or slight, sometimes associated with a severe conjunctivitis and edema of the lids, and at other times without any inflammatory symptoms being present. At times only a very small quantity of pus may be present in the inner canthus of the eye. At other times the reaction may manifest a true pyorrhea.

The reaction manifests itself in varying degrees in the animals, but the intensity of the reaction has no relation to the extent of the disease in the reactor.

RELIABILITY OF THE TEST.

The available data on the ophthalmic mallein test are sufficient to draw conclusions as to the reliability of the method, and in Austria alone it has been applied on many thousands of cases with uniformly good results.

In considering the good results obtained and the advantages of this method of testing, a concentrated mallein has been prepared for this purpose by the Bureau of Animal Industry, and this was made available to a number of practicing veterinarians who desired to give this method of testing a thorough trial. It has also been employed by inspectors of the Bureau of Animal Industry in their field work, and reports are accessible regarding its action for diagnostic purposes on more than 18,000 cases. The results from all sources were uniformly satisfactory. Practicing veterinarians who have given this method a trial have reported very favorably on the results, and the tests conducted by the bureau inspectors on several thousand animals were also satisfactory. The method has been applied here in Washington whenever possible, and recently in some immunizing tests of glanders conducted by the Bureau of Animal Industry there was a good opportunity to repeatedly employ this test. In all these instances the results were uniformly good. In cases of glanders there appeared a marked purulent conjunctivitis, and the reaction at times was so severe that the animal could not open its tested eye.

BEST RESULTS WITH RAW MALLEIN.

The essential factor in obtaining satisfactory results from the test appears to be in the use of the right kind of mallein. It must be by all means a concentrated mallein, and apparently the best results follow the use of raw mallein, which, as a rule, represents the mallein obtained after the concentration of the filtrate from the bouillon cultures of the glanders bacilli. The ordinary mallein used for subcutaneous testing is not adaptable, and the failures which have been reported in the literature were without doubt, in the majority of cases, due to the fact that the mallein employed was not sufficiently concentrated. Marioth[1] correctly asserts that the reaction does not depend as much on the quality and quantity of the mallein as on its concentration. Our experiments in preserving such mallein with the ordinary quantity of 0.5 per cent carbolic acid showed that it does not interfere with the results of the test, although the lacrimation which follows immediately after the introduction of such mallein is more profuse than when carbolic acid has not been added, but this disappears within one or two hours after the application of the test.

[1] Monatsh. f. prakt. Uerheilk., bd. 24, hft. 7/8, p. 340–373; hft. 9/10, p. 426–456. Stuttgart, 1913.

PREPARATION OF THE MALLEIN.

The concentrated mallein which has been used for our work and which gave such satisfactory results was prepared at the request of the authors by and in cooperation with Mr. A. M. West, of the Biochemic Division, as follows:

The media consists of bouillon containing 5 per cent glycerin, 1 per cent peptone, and 5 per cent NaCl. The reaction is that of the natural acidity of the meat, no acid or alkali being added. The flasks of media are inoculated with virulent cultures of *Bacillus mallei* and placed in the incubator at 37.5° C. for a period of two months or more. The stock cultures of *B. mallei* are kept on agar, and their virulence is renewed when necessary by passage through a series of guinea pigs.

The well-grown cultures show a heavy mass of organisms, which generally sinks to the bottom of the flask. This growth is of a whitish color splotched with brown. The cultures are then removed from the incubator and heated for one hour in the Arnold sterilizer. Then they are stored for two weeks in a dark closet to settle. The clear liquid is then carefully decanted and the growth proper is discarded.

A measured amount of the decanted liquid is concentrated over a steam bath to one-third its volume. It is then filled into flasks and sterilized and again filtered while hot, first through one then through three paper filters. Next the clear liquid is passed through a Berkefeld filter. This is followed by a concentration to one-tenth its original volume and by sterilization.

To the raw mallein, concentrated to one-tenth its original volume, is added 0.5 per cent carbolic acid and 20 per cent glycerin. Then the liquid is again concentrated to one-tenth its original volume, filtered while hot through filter paper, and sterilized. It is kept in a dark place for a week, and if upon inspection a precipitate is found the mallein is again passed through paper filters and sterilized. The finished product is a clear, sirupy, dark-brown liquid, with a disagreeable odor. The mallein is then bottled, under aseptic conditions, in small vials and is ready for use.

It is advisable to provide the mallein for the tests in small vials, each containing about 1.5 c. c. of mallein, which is sufficient for testing 15 horses. After the vial has been opened and part of the contents used for testing, especially if the mallein has been taken out with a camel's-hair brush, the remainder should not be used for tests applied on subsequent days, but should be discarded.

THE USE OF DRY MALLEIN.

Another form of mallein which has been used quite extensively for the eye test is the mallein siccum, or dry mallein. This represents an alcoholic precipitate of mallein. It is a fine gray powder and must be dissolved in water before it is used. The solution loses its effectiveness in a very short time and must be prepared fresh on the day of the test. Dr. K. F. Meyer, formerly of the University of Pennsylvania and now of the University of California, has used the dry mallein extensively, and at the present time this preparation is employed in Pennsylvania for the application of the ophthalmic test. For this purpose two vials are sent out from the laboratories of the Pennsylvania Livestock Sanitary Board, one containing the pow-

dered mallein and the other sterile or saline water in quantities which will make a 5 per cent solution of mallein. The content of the bottle containing the fluid is poured into the bottle containing the mallein powder and the test solution is thus prepared. The results with this form of testing in Pennsylvania appear to be highly satisfactory, as may be seen from a publication by Dr. Meyer on the "Conjunctival reaction for glanders," in the May, 1913, number of the Journal of Infectious Diseases.

The advantages of the use of one as compared with the other of these forms of mallein for the eye test are not marked, as equally good results were obtained from the application of both forms of this product. The fact that the preparation of the raw mallein is less laborious and expensive than the mallein siccum and that it is ready for use on opening the vial would probably give this product a greater popularity. It is only natural, however, that in the event subsequent extensive testings show the superiority of the dry mallein, it will be given preference over the raw product.

METHOD OF APPLYING THE TEST.

Before the application of the ophthalmic test the animals should be carefully examined to ascertain whether the eye shows conjunctivitis or other changes which are associated with suppuration. Should such be present the test should not be applied.

The test consists in introducing into the conjunctival sac of the eye several drops of either undiluted raw mallein or a solution of precipitated mallein (0.1 to 0.2 c. c. per horse). This may be introduced either with the aid of a camel's-hair brush or with an eyedropper. Only one eye is treated; the other serves as a control for comparison of the reaction. For the testing of horses in the same stable the same dropper or camel's-hair brush may be used for all the animals.

The results of the test should be recorded as follows:

N=Negative—eye unchanged.
S=Suspicious—seromucous discharge.
P+=Positive—seromucous discharge with purulent flakes.
P++=Positive—distinct purulent discharge.
P+++=Positive—purulent discharge with swelling of the eyelids.
P++++=Positive—strong purulent discharge with swelling and gluing together of both lids.

The following is a copy of Q. D. Form 69, Record of Ophthalmic Mallein Test, which is used by the Bureau of Animal Industry to record all official tests:

[Obverse.]

RECORD OF OPHTHALMIC MALLEIN TEST.

No. of animal.	Breed or markings.	Sex (stallion, gelding, or mare).	Age.	Weight.	Time of instillation.	Time of observation.		Temperatures, if taken.		Ante-mortem symptoms.	Results of test; decision.
					(Give date and hour.)			Before.	After.		

(Decision should be recorded in accordance with results obtained, by use of: [N]=Negative, eye unchanged. [S]=Suspicious, seromucous discharge. [P+]=Positive, seromucous discharge with purulent flakes. [P++]=Positive, distinct purulent discharge. [P+++]=Positive, purulent discharge with swelling of the eyelids. [P++++]=Positive, strong purulent discharge with swelling and gluing together of the lids.)

(Identify each animal by complete description; if necessary use two lines for an animal.)

[Reverse.]

RECORD OF REACTORS.

No. of animal.	Disposition of reactors (slaughtered or quarantined).	Date: .... Place of slaughter: .... Post-mortem by: ....
....	....	....
....	....	....
....	....	....
....	....	....
....	....	....
....	....	....
....	....	....
....	....	....
....	....	....
....	....	....
....	....	....
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....	....	....
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....	....	....
....	....	....
....	....	....
....	....	....
....	....	....
....	....	....

(Q. D. Form 69.)

U. S. DEPARTMENT OF AGRICULTURE,

BUREAU OF ANIMAL INDUSTRY.

Record of ophthalmic mallein test.

Name of person making test:

....

Address: ....

....

Dates: ....

Owner: ....

Address: ....

....

Number passed: ....

Number reacted: ....

Number suspicious: ....

Total number tested: ....

EFFECT OF THE TEST ON GLANDERED AND HEALTHY ANIMALS.

As soon as the mallein is introduced into the eye practically all animals show a lacrimation, increased reddening of the conjunctiva, and slight photophobia. No significance should be given to these symptoms. They disappear in one to two hours.

Glandered animals are hypersensitive to mallein in a way that the administration of small quantities of mallein produces local inflammatory processes. In larger quantities it produces a febrile general reaction. The hypersensitiveness appears as a rule during the third week after the infection, and reaches its height in the first few months after the infection. In the subsequent course it may subside in retrogressive cases even to the degree observed in healthy animals, but even in these cases various conditions may bring on an increased sensibility.

The characteristic manifestations of the reaction for glanders commence as a rule in from 5 to 6 hours and last 24 to 36 hours, some-

FIG. 1.—P + = Seromucous discharge with purulent flakes.

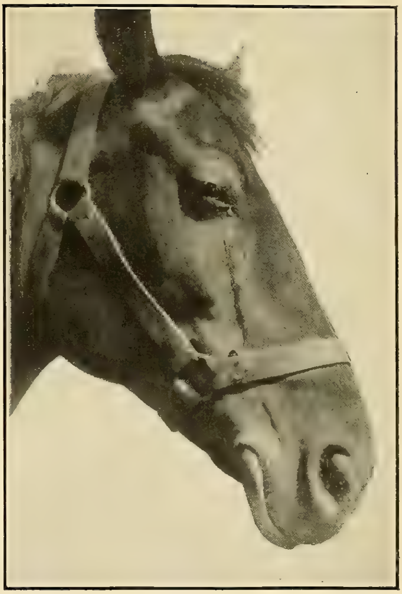

FIG. 2.—P+ + = Distinct purulent discharge.

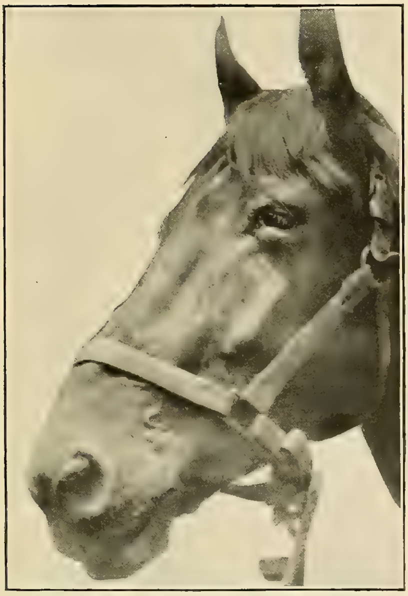

FIG. 3.—P + + + = Purulent discharge with swelling of the eyelids.

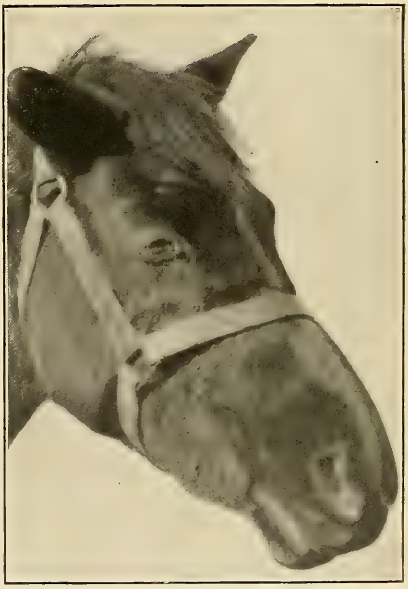

FIG. 4.—P + + + + = Strong purulent discharge with swelling and gluing together of both lids.

VARYING DEGREES OF REACTIONS IN THE OPHTHALMIC MALLEIN TEST FOR GLANDERS.

times longer. The reaction consists of a purulent discharge from the conjunctival sac which is typical, as well as swelling and gluing of the eyelids. It is advisable to examine the tested animals in a good light from 12 to 24 hours after the application of the test. Varying degrees of reactions are illustrated in Plate I, figures 1 to 4.

A suppurative discharge of varying quantities is considered a positive reaction. The conjunctiva and the eyeball should also be included in the examination after examining the discharge. A pseudo-reaction can be produced by artificial or accidental irritation of the eye. On the other hand the purulent discharge may have been removed (either by the stable attendant or by the animals licking each other, etc.), and the positive result thus obliterated. In such cases dried pus may be frequently found on the parts around the eye.

Generally the positive ophthalmic reactions are not accompanied by fever or systemic disturbances. Occasionally, however, affected horses are hypersensitive to such a degree that even the few drops of mallein placed in the eye may enter the circulation and produce fever. Therefore it is advisable, when possible, to accompany the ophthalmic reaction with temperature readings. For this purpose the temperature should be taken twice, the first time when the eye test is being made and the second time when it is judged. In a doubtful eye reaction, where there is an increased temperature of $1\frac{1}{2}$ degrees F., the test should be considered positive if the animal had a normal temperature at the time the test was made. As stated before, it should be remembered that the intensity of the reaction has no relation to the extent of the disease in the animal tested.

In the absence of any secretion the test should be considered negative. When there is a mucous secretion or lacrimation during the period of reaction the test must be considered as atypical, and in such cases it may be repeated the same day, when, as a rule, the results are more confirming.

The application of the ophthalmic test should not be repeated more than three times on the same animal within three months, as experiments show that the reaction after the third application within this short period usually loses its intensity in positive cases, and on subsequent tests may be entirely absent. In cases where the results of the second test immediately following the first test are atypical, the blood of such animal may be drawn and forwarded to a laboratory for the serum diagnosis. From experience gained with the eye test such a procedure would become necessary only in a comparatively few cases. In the control of glanders, animals may be retested every six months with satisfactory results.

REPORT OF THE AMERICAN VETERINARY MEDICAL ASSOCIATION ON THE OPHTHALMIC TEST.

The special committee on the control of glanders of the American Veterinary Medical Association has issued a most excellent report on the various phases of diagnosis of glanders. The conclusions on the value of the eye test offered by this committee are in perfect accord with our findings, we therefore deem it advisable to include them in this paper, as follows:

1. The ophthalmic test not only meets all the requirements, but is without doubt the most convenient diagnostic method at our command.
2. Its reliability compares favorably with any of the other tests available.
3. The reaction is usually very distinct, and doubtful or atypical reactions are rather infrequent.
4. The ophthalmic test has the advantage that it does not interfere with subsequent serum or other mallein tests if such are deemed necessary.
5. The test may be repeated within 24 hours on same or control eye. If another retest is necessary, it should not be made in less than three weeks.
6. The ophthalmic test should be recognized by State and Federal authorities, since its reliability can no longer be doubted.
7. In all atypical and doubtful cases of the ophthalmic test, the combined complement-fixation and agglutination or subcutaneous mallein test should be utilized for confirmation. Such a procedure would minimize the failure and would assure the best results in the control of the disease in a single stable or in an entire community.

CONCLUSION.

The results achieved in Austria with the ophthalmic test have been remarkably successful and deserve the most earnest consideration. The report of Prof. Schnurer on The Results of the Diagnostic Procedure in Glanders in Austria is a convincing proof as to the value of the eye test in the control of glanders. The senior writer received a communication only a short time ago from Prof. Schnurer, and since it deals principally with the diagnostic value of the eye test, a quotation from the letter will no doubt be permissible:

I am at the present contemplating collecting the results of the eradication of glanders in Austria during the last three years (1910–1912). During this time 60.894 tests were undertaken on 47,973 horses. Of 272 cases which were found on post-mortem to be affected with glanders 240 (88.2 per cent) were positive, 21 (7.7 per cent) gave an atypical reaction, while 11 (4 per cent) were negative. Of the 47,701 healthy horses, 189 (0.39 per cent) were positive or atypical, the remaining 47,512 (99.61 per cent) gave a negative reaction.

According to these results, therefore, the eradication of glanders is only a question of organization—that is, the malleinization of horses at the border and conscientious following up of all suspected horses. Such procedure would, without doubt, result in a complete eradication of glanders. At the Veterinary School of Austria we now have difficulty in showing the student cases of glanders, and for demonstration purposes we are compelled to infect horses artificially, whereas several years ago we had every week at least one case of glanders in our clinics.

I use as mallein at the present time a product which I, myself, prepare, which represents a bouillon filtrate from seven different strains of glanders bacilli which has been concentrated to one-tenth of the original volume

The optimistic view of Prof. Schnurer is certainly justified from the results he achieved, and clearly shows that with proper organization in the control work of glanders the eradication of the disease is only a question of time.

The eradication of outbreaks of glanders can not, of course, be altogether attributed to the eye test, since from the report of Nevermann, veterinary councilor of Prussia, glanders has diminished remarkably in that country, where they employ the combined complement-fixation and agglutination test for the diagnosis, while McGilvray has practically eradicated glanders from the Province of Manitoba by means of the subcutaneous mallein test. The method of testing by means of complement-fixation and agglutination is undoubtedly the most accurate of any available, but since it can not be as conveniently applied as the eye test, its disadvantages are apparent. There is no doubt that with the application of either the eye test or the combined complement-fixation and agglutination tests, equally good results may be obtained provided that the work is conscientiously carried out and that all the reactors are destroyed without hesitation.

As long as the authorities will limit themselves to the destruction of clinical cases only and will not take immediate action on reactors of the occult and latent character, glanders will not only continue to exist, but it will spread.

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Contribution from the Bureau of Entomology, L. O. Howard, Chief.
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(PROFESSIONAL PAPER.)

PARA-DICHLOROBENZENE AS AN INSECT FUMIGANT.

By A. B. Duckett,
Scientific Assistant, Truck Crop and Stored Product Insect Investigations.

INTRODUCTION.

The purpose of the following pages is to determine the insecticidal value of para-dichlorobenzene as a fumigant, as well as to ascertain the injury, if any, to cloth fabrics and the effects of the vapors on plant life as well as upon the germination of seeds.

Para-dichlorobenzene is a definite chemical compound, known for many years, but only recently used as an insecticide. It is a colorless, crystalline substance which volatilizes very readily as a colorless vapor with a peculiar ether-like odor. The vapor is harmless to human beings and domestic animals under ordinary conditions, but in many instances it is a specific poison for insects. It has an additional advantage over the many other fumigants in that the odor does not cling to fabrics, etc., the characteristic ether-like smell rapidly disappearing upon exposure of the fumigated substances to the open air. Probably the greatest advantages that para-dichlorobenzene possesses over other fumigants are its absolute noninflammability and its comparatively low cost of purchase and application in proportion to the result obtained.

EFFECTS OF INHALATION OF THE VAPOR.

As stated, para-dichlorobenzene possesses only a weak ether-like smell, which, owing to the volatile nature of the substance, will pass off in a few hours if exposed to the air. Dr. Curschman, at the Greppin Works in Germany, concludes from a series of experiments that para-dichlorobenzene, when used as an exterminator for moths, etc., is virtually harmless to human beings, perhaps even superior to naphthalene in this respect. He goes further by stating that poisoning by para-dichlorobenzene to human beings through contact with the skin is impossible and that inhalation of the vapors of this product is perfectly harmless. According to him, para-dichloro-

benzene is harmful to human beings only in cases of internal application of large quantities, say from 30 to 40 grains.

It is not advisable for sensitive persons to remain for a long time in a closed room where para-dichlorobenzene is freely exposed, as the odor may cause annoyance. On the other hand, para-dichlorobenzene can be used in closed or occasionally opened cupboards and even in sitting rooms without causing any inconvenience whatsoever.

PARA-DICHLOROBENZENE AS AN INSECTICIDE.

Experiments were conducted by the writer with para-dichlorobenzene to ascertain the practicability of its use and its insecticidal value against various insects. Para-dichlorobenzene as an insecticide is applicable to a large variety of insects, but under certain conditions depending on the variations in life history and environment, and therefore necessitating specific methods of application.

In a general way para-dichlorobenzene is effective only where its vapors can be closely confined, and when used in a higher temperature than 74° F.; furthermore, it is recommended only where poison bait and contact sprays are either impractical or undesirable. The vapor is diffused through the air very rapidly and must, therefore, be closely confined in order to maintain a sufficient proportion in the air to prove fatal to insect life.

The amount of material required, under ordinary conditions, to bring about the desired effect is about 12 ounces of para-dichlorobenzene to every 100 cubic feet of space. The writer, however, suggests the use of a larger amount, 1 pound to 100 cubic feet, which will take effect more quickly and diminish the chances of revival, although revival is aberrent. At temperatures between 75° and 85° F. an exposure of at least 36 hours is necessary for best results. Temperatures above 85° F. require only 24 hours exposure, due to the fact that heat facilitates the diffusion of the vapors.

Most warehouses and repositories contain several species of insects which possess very great tenacity of life, either in the adult or larval stages. In view of the fact that unless para-dichlorobenzene is used in enormous quantities or is permitted to remain in the respository over 48 hours, it does not injure plant life or render fruit, etc., inedible, we should, by preference, use as large a dose as possible for the complete eradication of the insects in the shortest possible time. As generally employed, the time would vary inversely to the amount of para-dichlorobenzene used. Since this substance is comparatively cheap and all unvolatilized material can be kept indefinitely, with very slight deterioration if the proper precautions are exercised, the additional amount of material required for a larger dose would be an insignificant item. Para-dichlorobenzene is insoluble in water and does not deliquesce when exposed to the air, but completely volatilizes, and should therefore be kept in an air tight can or glass jar.

DIFFUSION OF THE VAPOR.

Para-dichlorobenzene is very volatile and the vapor is extremely heavy, being more than five times that of an equal volume of air and more than twice as heavy as carbon bisulphid vapor. Although it diffuses quite rapidly through the air, as evidenced by the perception of its odor, the vapors will, like carbon bisulphid, tend to work rapidly downward, outward, and eventually upward. From the foregoing fact it is ascertained that the greater density of vapor is at the lower levels. This property is obviously very beneficial when para-dichlorobenzene is used as a fumigant for bags of grain, stored products, carpets, and rugs, and in all cases where it is desirable to use a gas that will penetrate the lowest levels and force its way into cracks and crevices in floors, walls, and similar locations.

DIRECTIONS FOR USING.

Para-dichlorobenzene is applied in most instances in the same manner as camphor and naphthalene. It is not, however, necessary to sprinkle it around in corners or over rugs and other material, as is often the case with camphor and naphthalene, but merely to expose a sufficient quantity in one or two open or partially open receptacles, placed over, or higher, than the infested cases, goods, and material which require fumigation.

HOW PUT UP AND COST.

Para-dichlorobenzene at the present time is sold in 5, 10, 25, 50, and 100 pound and barrel lots, the prices for which are as follows:

23 cents per pound, in 5, 10, and 25 pound lots.
18 cents per pound, in 50-pound lots.
17 cents per pound, in 100-pound lots.
15 cents per pound, in barrel lots.

If any considerable quantity is to be used, it is much better to purchase of some wholesale druggist or direct from the manufacturers.

APPLICABILITY TO VARIOUS INSECTS.

Para-dichlorobenzene is applicable to many insect pests living under various conditions and environment, and therefore requires specific methods of application, and, unlike carbon bisulphid, it is at the present time used only indoors and in other places where its vapors can be closely confined. As there is a great variation in the tenacity of life among insects, the existing conditions should be carefully noted before para-dichlorobenzene is applied.

Beetles, such as the rice weevil (*Calandra oryza* L.), granary weevil (*Calandra granaria* L.), the confused flour beetle (*Tribolium confusum* Duv.), the cadelle (*Tenebroides mauritanicus* L.), the yellow

mealworm (*Tenebrio molitor* L.), and a few others less common are particularly hard to kill when in the adult stage. The larvæ of the mealworms, *Tenebrio molitor* L., *Tenebrio obscurus* L., and closely allied species, are likewise found by experiment to possess great tenacity of life. It is therefore recommended that a proportionately larger amount of para-dichlorobenzene be used when combating these species. Moths, flies, roaches, ants, and aphides are readily killed by para-dichlorobenzene when used in the ordinary strength recommended under the heading "Para-dichlorobenzene as an insecticide."

The action of para-dichlorobenzene on insects is primarily upon their nervous systems. This property is readily manifested when a moth is exposed to the vapors for a few seconds. It first displays great excitement and uneasiness, followed closely by spasmodic convulsions, and finally turns over on its back. While in this position violent nervous and muscular reflex action is noticed until life is extinct.

The moths on which this gas has been tested include the Angoumois grain moth (*Sitotroga cerealella* Oliv.), Mediterranean flour moth (*Ephestia kuehniella* Zell.), Indian meal moth (*Plodia interpunctella* Hbn.), meal snout moth (*Pyralis farinalis* L.), and the case-bearing clothes-moth (*Tinea pellionella* L.).

EXPERIMENTS WITH PARA-DICHLOROBENZENE AS A FUMIGANT.

During the spring of 1914, while stationed at Washington, D. C., the writer, working under the direction of Dr. F. H. Chittenden, performed a series of experiments with para-dichlorobenzene as a fumigant for stored-product insects. The chemical was first used on a small scale, and results were afterwards checked up in a specially constructed air-tight fumigating box having a capacity of 100 cubic feet (Pl. I.) The average temperature was computed from the records of a thermograph placed in the box, and the para-dichlorobenzene exposed in shallow piepans or the tops of 5-gallon lard cans, since these shallow receptacles present a much larger surface of the chemical for evaporation. These pans were placed about 4 feet above the material to be fumigated, which was contained in muslin bags of variable capacity (see Pl. II) and which had previously been ascertained to be free from live insects. Into this material, consisting of wheat, cornmeal, flour, rice, and other cereals, were then introduced living insects, the number and species of each being recorded on an attached tag.

The respective amounts of para-dichlorobenzene used in each experiment and the tabulated results follow.

FUMIGATING BOX USED IN EXPERIMENTS WITH PARA-DICHLOROBENZENE. (ORIGINAL.)

BAGS CONTAINING INFESTED GRAIN READY TO BE FUMIGATED WITH PARA-DICHLOROBENZENE.
(ORIGINAL.)

Experiments with para-dichlorobenzene as a fumigant.

Experiment No. and date.	Insects introduced.	Average temperature.	Length exposure.	Date examined.	Para-dichlorobenzene used.	Per cent killed.	Remarks.
		° F.	*Hours.*				
No. 1, Mar. 25, 1914.	Tribolium confusum Duv.; T. ferrugineum Fab.; Calandra oryza L.; C. granaria L.; Silvanus surinamensis L.; Rhizopertha dominica Fab.; Laemophloeus minutus Oliv.; Tenebrio molitor L.; Sitotroga cerealella Oliv.; Plodia interpunctella Hbn.; Ephestia kuehniella Zell.	52	72	Apr. 1	1 ounce.	None.	All revived. Preliminary ttest. Temperature too low. Vapors diffused very slowly. Eggs, larvæ, pupæ, and adults used in the case of Ephestia kuehniella and Plodia interpunctella. Capacity of fumigating box used, 7 cubic feet.
No. 2, Apr. 7, 1914.	Same as in experiment No. 1.	59	96	Apr. 13	8 ounces.	None.	All revived. Preliminary test. Temperature too low. Fumigating box used, 7 cubic feet.
No. 3, Apr. 18, 1914.	Same as in experiment No. 1.	65	96	Apr. 25	8 ounces.	20	Unsatisfactory. Preliminary test. Fumigating box used, 7 cubic feet.
No. 4, Apr. 28, 1914.	Tribolium confusum Duv.; T. ferrugineum Fab.; Calandra oryza L.; C. granaria L.; Silvanus surinamensis L.; Rhizopertha dominica Fab.; Sitotroga cerealella Oliv.; Plodia interpunctella Hbn.; Ephestia kuehniella Zell.; (Bruchus) Pachymerus 4-maculatus Fab.	81	24	May 5	2 pounds	100	100 cubic feet fumigating box used for this experiment.
No. 5, Apr. 29, 1914.	Roaches	80	24	May 2	2 ounces.	100	5 cubic feet fumigating jar used.
No. 6, May 1, 1914.	Mites on corn	78	28	May 5	2 ounces.	100	5 cubic feet fumigating jar used.
No. 7, May 4, 1914.	Slugs, snails, sowbugs, millipedes, ants.	82	36	May 9	2 pounds	100	100 cubic feet fumigating box used.
No. 8, May 11, 1914.	Tribolium confusum Duv.; Calandra oryza L.; Silvanus surinamensis L.; Sitotroga cerealella Oliv.; Plodia interpunctella Hbn.; Ephestia kuehniella Zell.; Laemophloeus minutus Oliv.; Tenebrio molitor L.	86	24	May 16	2 pounds	100	100 cubic feet fumigating box used in this experiment. Four bricks were heated to a high temperature and placed in box in order to obtain higher temperature.
No. 9, May 14, 1914.	Same as in experiment No. 8.	73	24	May 20	2 pounds	70	Unsatisfactory. Temperature too low.
No. 10, May 15, 1914.	Flies	81	20	May 16	8 ounces.	100	100 cubic feet space.
No. 11, May 18, 1914.	Aphides	80	20	May 19	8 ounces.	100	100 cubic feet space.

No. 12. May 19, 1914, 4 ounces of finely ground para-dichlorobenzene were sprinkled over pieces of woolen cloth and placed in a 100-cubic-foot fumigating box for a period of 24 hours, at an average temperature of 76° F. Upon examination it was discovered that the fine crystals adhered to the lint of the wool but were readily brushed off with a whisk broom. After two hours' exposure in the open air the odor of para-dichlorobenzene was barely perceptible.

No. 13. May 20, 1914, a test on the germination of seed was made. One pint of Argentine corn, about half of which had previously sprouted, was put in a 7-inch flower pot containing 4 inches of moist fertile soil. The pot was then introduced into a 100-cubic-foot fumigating box and exposed to the vapors of para-

dichlorobenzene for 24 hours at an average temperature of 79° F. Two days later the seed was examined and showed no material injury from the experiment, sprouting about as usual.

NOTE.—Preliminary experiments with para-dichlorobenzene have been conducted along the following lines: 1. Para-dichlorobenzene introduced into insect collection boxes for the eradication of museum pests. 2. Para-dichlorobenzene in combination with formaldehyde and potassium permanganate as an insecticide and germicide. 3. Para-dichlorobenzene made into a paste by adding paraffin and resin in the presence of heat, as a substitute for grafting wax. The above paste to be applied in the burrows of borers in shade trees. 4. Further experiments on the effect of para-dichlorobenzene, if any, on tender plants. 5. The effects, if any, of para-dichlorobenzene on animals, when taken internally in small doses. In these experiments green food, such as kale, cabbage, and clover, were put in a jar heavily charged with para-dichlorobenzene vapors and fed twice daily to herbivorous animals, such as rabbits and guinea-pigs. In these experiments the writer has not as yet reached any definite conclusions, and therefore reserves their publication until further experiments along these lines are completed.

CONCLUSION.

From the foregoing observations and experiments the writer concludes that para-dichlorobenzene, used as directed in the preceding pages, acts as an excellent fumigant against the following insects:

(1) Stored-product insects.
(2) Case-bearing clothes moths.
(3) Roaches and ants.
(4) Museum pests.
(5) Miscellaneous house insects, including flies, carpet beetles or buffalo moths, book lice, silverfish, mosquitoes, centipedes, and miscellaneous larder insects.

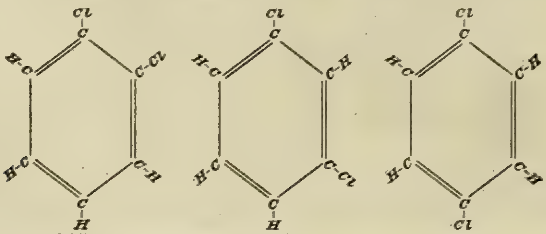
It is also an effective substitute for potassium cyanid in collecting bottles.

CHEMICAL AND PHYSICAL PROPERTIES OF PARA-DICHLOROBENZENE.

At the request of Dr. Chittenden the following data were kindly furnished by the Insecticide and Fungicide Laboratory, Miscellaneous Division, Bureau of Chemistry:

We have made an examination of the sample of dichlorobenzene submitted by you for examination on December 22, 1913, and find that this product is practically pure para-dichlorobenzene ($C_6H_4Cl_2$). We have looked up some references in the literature in regard to this substance and give you the following information based thereon:

Dichlorobenzene is a product derived from benzene by the replacement of two of the hydrogen atoms by chlorine. There are three dichlorobenzenes, designated ortho, meta, and para, the structural formulas of which are:



ORTHO META PARA

All three have the empirical formula $C_6H_4Cl_2$. Ortho and meta dichlorobenzenes are liquids, the former boiling at 179° C. and the latter at 172° C.

Beilstein, in his Handbuch der organischen Chemie, III Auflage, 1896, Band II, page 44, gives three methods for the preparation of para-dichlorobenzene (in the German, p-dichlorbenzol):

(1) By the action of chlorine on benzene (C_6H_6) in the presence of iodine. A little ortho-dichlorobenzene is also formed in this reaction.

(2) By the action of phosphorus pentachlorid on para-chlorophenol.

(3) By the action of phosphorus pentachlorid on para-phenolsulphonic acid.

He gives the melting point of this compound as 53° C. (127.4° F.) and its boiling point as 172° C. (341.6° F.), but quotes Mills (Phil. Mag. (5) 14, 27) as giving 52.72° C. for the melting point.

Para-dichlorobenzene crystallizes from alcohol in monoclinic leaves, it sublimes at ordinary temperatures, is soluble in hot alcohol in all proportions, and is easily soluble in ether, benzene, carbon bisulphid, etc.

In regard to physiological properties, Francis and Fortescue-Brickdale [1] state:

> The benzene halogen derivatives have a slight odor, are insoluble in water, volatilize without decomposition, and are very stable. * * * Corresponding to their stability it is found that the halogen is not split off in the organism, and that they do not show hypnotic properties. With the entrance of chlorine the antiseptic properties increase * * * Chlorbenzene acts on the spinal cord to a greater extent than benzene.

The following figures in regard to para-dichlorobenzene are from calculations made by R. C. Roark:

Molecular weight	146.952	
Density of the vapor	4.592	if oxygen equals 1.
	72.892	if hydrogen equals 1.
	5.1025	if air equals 1, assuming the molecular weight of air to be 28.8.

In other words, assuming no dissociation or association, a given volume of para-dichlorobenzene in the form of a vapor would be 5.1025 times as heavy as an equal volume of air at the same temperature and at the same barometric pressure.

The vapor of para-dichlorobenzene will flash at about 70° C. (158° F.), but even when held in a very hot flame and ignited the substance will not continue to burn after the flame is removed. Thus the substance is not combustible, but is decomposed by heat into substances which partially burn with copious deposition of soot when directly in a flame.

As the vapor pressure of para-dichlorobenzene has never been determined, it is impossible to state how much of its vapor air at any temperature short of 172° C. (341.6° F., its boiling point) would take up. At 172° C. (341.6° F.), barometer 760 mm., 1 liter of para-dichlorobenzene gas would weigh 4.0257 grams, or 1 cubic foot would weigh 4.0208 avoirdupois ounces.

[1] Francis, Francis, and Fortescue-Brickdale, J. M. The Chemical Basis of Pharmacology, p. 99, London, 1908.

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BULLETIN OF THE U.S. DEPARTMENT OF AGRICULTURE

No. 168

Contribution from the Bureau of Plant Industry, Wm. A. Taylor, Chief.
July 15, 1915.

GRADES FOR COMMERCIAL CORN.

By J. W. T. Duvel,
Crop Technologist in Charge of Grain-Standardization Investigations.

CLASSIFICATION OF CORN.

By virtue of the authority vested in the Secretary of Agriculture by the acts of Congress of June 30, 1906 (34 Stat., 669), and of March 4, 1913 (37 Stat., 828), to fix definite grades of grain, the grades for corn shown in Table I were fixed and promulgated on January 3, 1914, to take effect on July 1, 1914.

Table I.—*Grade classification of white, yellow, and mixed corn, showing maximum allowances of moisture and other factors.*

Grade classification.	Maximum allowances of—			
	Moisture.	Damaged corn.	Foreign material, including dirt, cob, other grains, finely broken corn, etc.	"Cracked" corn, not including finely broken corn. (See general rule No. 9.)
	Per cent.		*Per cent.*	*Per cent.*
No. 1	14.0	2 per cent (exclusive of heat-damaged or mahogany kernels)	1	2
No. 2	15.5	4 per cent (exclusive of heat-damaged or mahogany kernels)	1	3
No. 3	17.5	6 per cent (exclusive of heat-damaged or mahogany kernels)	2	4
No. 4	19.5	8 per cent (may include heat-damaged or mahogany kernels not to exceed one-half of 1 per cent)	2	4
No. 5	21.5	10 per cent (may include heat-damaged or mahogany kernels not to exceed 1 per cent)	3	5
No. 6	23.0	15 per cent (may include heat-damaged or mahogany kernels not to exceed 3 per cent)	5	7
Sample		See general rule No. 6 for sample grade		

GENERAL RULES.

(1) The corn in grades No. 1 to No. 5, inclusive, must be sweet.

(2) White corn, all grades, shall be at least 98 per cent white.

(3) Yellow corn, all grades, shall be at least 95 per cent yellow.

(4) Mixed corn, all grades, shall include corn of various colors not coming within the limits for color as provided for under white or yellow corn.

(5) In addition to the various limits indicated, No. 6 corn may be musty, sour, and may also include that of inferior quality, such as immature and badly blistered corn.

(6) All corn that does not meet the requirements of either of the six numerical grades by reason of an excessive percentage of moisture, damaged kernels, foreign matter, or "cracked" corn, or corn that is hot, heat damaged, fire burnt, infested with live weevils, or otherwise of distinctly low quality shall be classed as sample grade.

(7) In No. 6 and sample grades, the reasons for so grading shall be stated on the inspector's certificate.

(8) Finely broken corn shall include all broken particles of corn that will pass through a metal sieve perforated with round holes nine sixty-fourths of an inch in diameter.

(9) "Cracked" corn shall include all coarsely broken pieces of kernels that will pass through a metal sieve perforated with round holes one-quarter of an inch in diameter, except that the finely broken corn, as provided for under rule No. 8, shall not be considered as "cracked" corn.

(10) It is understood that the damaged corn, the foreign material (including dirt, pieces of cob, finely broken corn, other grains, etc.), and the coarsely broken or "cracked" corn, as provided for under the various grades, shall be such as occur naturally in corn when handled under good commercial conditions.

(11) Moisture percentages, as provided for in these grade specifications, shall conform to results obtained by the standard method and tester described in Circular No. 72, Bureau of Plant Industry, U. S. Department of Agriculture.

HOW THE VARIOUS FACTORS SHOULD BE DETERMINED.

In order that producers, dealers, and consumers throughout the United States may fully understand the correct interpretation of the Government corn grades, somewhat detailed explanations are given in the following pages.

In the practical application of these grades it is fully appreciated that even with definite limits for the more important factors points will arise on which the best of experts may differ. For example, there are all degrees of damage and wide variations in color, so that some arbitrary line must be drawn as to what shall be considered as commercially sound or what shall be considered as white or as yellow. Similar conditions exist on other points. It is believed, however, that by the honest adherence to the instructions which follow differences in grading will be reduced to a minimum and that the grades can be uniformly applied throughout the United States.

While these explanations are given somewhat in detail and definite limits have been fixed for the more important factors, it is not contemplated that actual determinations shall be made in the grading of every lot of commercial corn. In a large number of cases a competent and experienced inspector or grader, after he has once become familiar with the various limits fixed and established in these grades, can estimate the percentage of the various factors with sufficient accuracy to determine the grade thereof on the basis of his judgment.

SECURING A REPRESENTATIVE SAMPLE FROM THE BULK.

In the grading of commercial corn no factor is of greater importance than the securing of a sample representative of the bulk. Likewise, no factor is more frequently neglected. In the application of these grades to car-lot shipments of corn it is recommended that not less than five probes with a suitable grain trier be taken in such a way that the composite sample thus secured will represent the average of the car as nearly as practicable. On cars not uniformly loaded, such additional probes should be made as, in the opinion of the sampler, may be necessary to secure a representative sample. In cars that show distinct evidence of having been "plugged," and in all cases of marked variation in the quality or condition of the corn in different parts of the lot being examined, a separate composite sample should be taken to represent each such portion.

If only a part of the grain secured by the various probes is taken to a central office for more careful examination and final grading, the mixing of the individual sample at the car should receive most careful consideration. Very satisfactory results can be secured by emptying the contents of the trier each time on a piece of canvas and, after all probes have been made, thoroughly mixing the samples on the canvas, finally rolling the sample on the canvas, somewhat as an expert would roll a cigarette, except that the canvas should be held by two opposite sides, which two sides should be securely fastened to a stick or rod. The larger composite sample can then be readily divided into two approximately equal parts by seizing the fold of the canvas from beneath with the thumb and index finger; then, emptying one portion into the car, the other is retained for the office sample.

Representative samples can not be secured by emptying the contents of the trier, after each probe, on top of the grain, then roughly mixing and taking a portion thereof, usually including a part of the surface corn, as a composite sample for the basis of grading. Such samples not only fail to represent the bulk, but are misleading, especially from the standpoint of dirt and cracked corn. Likewise, composite samples made up by emptying only a part of the contents of the trier into the can or sample bag can not, as a rule, be considered representative.

In the sampling of large lots of grain, such as occur in the loading of steamers, at least one representative sample made up of a series of samples from the various drafts should be taken for each 5,000 bushels.

In the sampling of ear corn, where the moisture content is the important factor, at least 20 representative ears should be taken at random for each 1,000 bushels. In wagon lots of 100 bushels or

less, at least 10 representative ears should be selected for test. In all ear-corn samples where it is impracticable to shell completely all of the selected ears, an approximately equal portion should be shelled from the same point or points on each ear. A simple and satisfactory method is to break the ears near the middle and then shell from the broken ends. In ear corn the damage can usually be very closely estimated by classifying a limited number of ears, but for a more exact determination it will be necessary to shell the selected number of ears completely and determine the percentage of damaged kernels in the regular manner.

MIXING SAMPLES FOR DETAILED ANALYSES.

Care should be taken to see that the samples used for the detailed analyses are representative of the larger sample as drawn from the car or other bulk.

A special sampling or mixing machine for this purpose has been developed. This mixing machine will be described in detail in a later bulletin of the Department of Agriculture.

SIZE OF SAMPLES.

The samples taken from the car or other bulk on which the grading is to be based should consist of not less than 1 quart of shelled corn.

The samples for the more detailed analyses, taken from the larger sample representing the bulk, should be as follows:

Moisture content.—100 grams for each single test.

Color.—Not less than 100 grams of screened corn.

"Cracked" corn and foreign material, dirt, etc.—At least 200 grams of the carefully mixed sample. In using a 200-gram sample it must be remembered that the weight in grams of each of the two factors must be divided by 2 to ascertain the percentage.

Damaged corn.—Preferably, on the whole of what remains of the sample after removing the cracked corn, the foreign material, dirt, etc. In this connection it should be remembered that the percentage of damaged corn should be based not on the weight of the screened sample but on the weight of the sample taken for analysis before removing the cracked corn, the foreign material, dirt, etc. For example, in a 200-gram sample showing 3 per cent of cracked corn and 2 per cent of foreign material, dirt, etc., there would remain 190 grams to be analyzed for damaged kernels. Damaged kernels weighing 20 grams based on the original 200-gram sample would therefore be equivalent to 10 per cent, whereas if incorrectly based on only 190 grams the percentage of dirt would show as 10.4 per cent.

SIEVES FOR SCREENING SAMPLES.

The sieves for screening the samples should be made of metal perforated with round holes. The holes in the upper or first sieve should be one-quarter of an inch in diameter and the holes in the lower or second sieve nine sixty-fourths of an inch in diameter. Figures 1 and 2 show these holes of natural size and the approximate

distance from center to center. The thickness of the metal should be from 0.025 to 0.035 of an inch.

Round sieves from 10 to 12 inches in diameter or rectangular sieves 9 by 11 inches have been found very satisfactory and easy to manipulate. For the most efficient work, the two sieves with the bottom pan should be made to nest, so that all screening can be done at one operation.

It is recommended that the sieves be made of brass, aluminum, or other suitable metal, pressed from one piece, although sieves made by soldering or nailing the perforated metal to any suitable frame will give satisfactory results if kept in good repair.

If made to nest, as shown in figure 3, the depth of the first sieve should be $1\frac{1}{2}$ inches, the second 2 inches, and the bottom pan $2\frac{1}{2}$ inches.

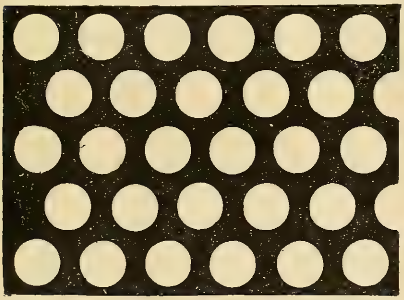

Fig. 1.—Section of sieve with perforations one-fourth of an inch in diameter, the distance from center to center of holes being approximately eleven thirty-seconds of an inch.

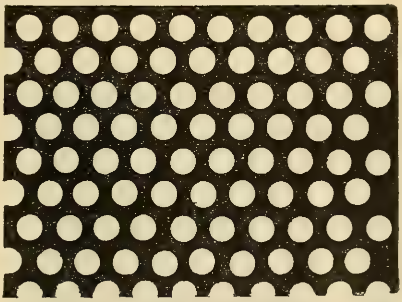

Fig. 2.—Section of sieve with perforations nine sixty-fourths of an inch in diameter, the distance from center to center of holes being approximately thirteen sixty-fourths of an inch.

If made of metal, at least the bottom pan should be of aluminum, to reduce the weight, thereby facilitating the ease of handling.

MOISTURE TESTS.

In determining the moisture content, it is desirable that all important samples be tested in duplicate whenever practicable and the final result based on the average of the two tests. Results of tests need not be expressed closer than one-tenth of 1 per cent, and the grain should be given the benefit of the doubt in computing averages. For example, in taking the average of two tests, one showing 19.3 per cent and the other 19.4 per cent, the true average would be 19.35 per cent, but when used in connection with these grades the moisture content should be recorded as 19.3 per cent and not 19.35 per cent. Likewise, in single tests any reading in the second decimal place may be ignored in moisture determinations.

Owing to the numerous methods of making moisture determinations and the wide variations in the results obtained by the different methods, the tester and method described in Circular No. 72 of the

Bureau of Plant Industry, United States Department of Agriculture, have been designated as the standard on which the grades have been based. Copies of this circular can be secured upon application to the United States Department of Agriculture. This in no way precludes the use of other methods of making moisture determinations, so long as the results are corrected to conform to those secured by the standard method specified. Figure 4 represents a sectional view of the standard tester that is recommended. The United States patent covering this tester has been donated to the people of the United States, so that the tester can be used, manufactured, or sold by any citizen within the United States without the payment of royalty.

DAMAGED CORN.

As shown in the grade classification (Table I), the grades 1, 2, and 3 may contain not to exceed 2, 4, and 6 per cent, respectively, of damaged corn, such as "cob-rotten" corn, "blue eyes," etc., but these first three grades shall not include heat-damaged or mahogany kernels. Grades 4, 5, and 6 may contain not to exceed 8, 10, and 15 per cent, respectively, of damaged corn, a portion of which may consist of heat-damaged or mahogany kernels. The heat-damaged or mahogany kernels permissible as a part of the damaged corn shall not exceed one-half of 1 per cent in No. 4 grade, 1 per cent in No. 5 grade, and 3 per cent in No. 6 grade; but the total damaged in these three grades shall not exceed 8, 10, and 15 per cent, respectively.

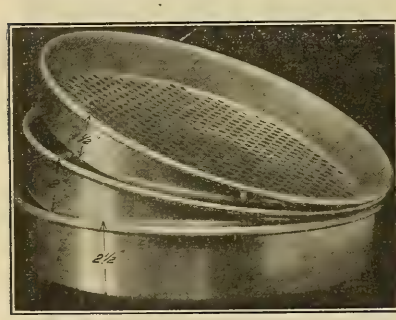

FIG. 3.—Nest of two sieves and bottom pan used in grading corn.

Types of damaged kernels.—An attempt has been made to show in natural colors by means of kernels numbered 1 to 26 in Plate I types of kernels which should be classed as damaged. These types of damage range from the badly "silk-cut" kernels, shown in No. 1 (front and back of same kernel), to the very badly "cob-rotten" kernels shown in No. 26. These types also include badly shriveled kernels which have failed to ripen (shown by kernels numbered 14 and 15). However, skeleton kernels similar to this type, when consisting of nothing but the skin of the kernel or of such a character that they would be removed by light blowing or fanning, should be classed as foreign material and not as damaged corn. Types of such skeleton kernels are shown in figure 5.

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TYPES OF KERNELS OF CORN FOR USE IN GRADING.

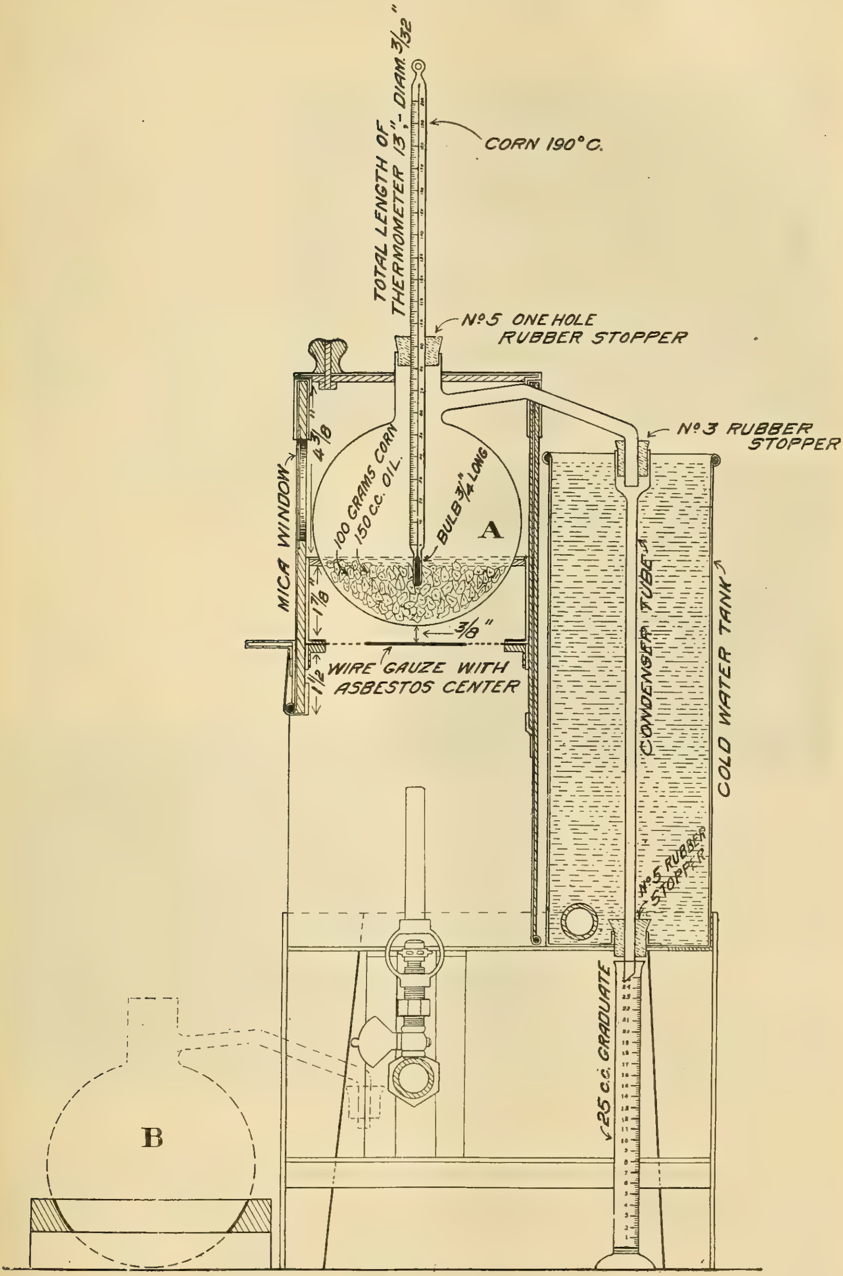

FIG. 4.—Sectional view of standard moisture tester.

Heat-damaged and mahogany kernels.—Corn which has become discolored as a result of heating due to fermentation or fire damage shall be classed as "heat damaged." Badly discolored and darkened kernels shall be classed as "mahogany" corn. No heat-damaged kernels are shown in the colored plate.

DETERMINATION OF DAMAGED CORN.

The percentage of damage should be made on the screened sample, preferably by using the entire quantity that remains after removing the foreign material and "cracked" corn. In order to simplify the determination for damaged corn and to avoid a double penalty, the damaged "cracked" corn, as used in these grades, shall be considered simply as "cracked" corn; that is, the small quantity of damaged "cracked" corn should not be picked out after screening and classified as a part of the damaged corn. An excess of damage in the "cracked" corn will be evidence of a willful adulteration and a violation of general rule No. 10 of the grades.

FIG. 5.—Immature skeleton kernels which would be removed by fanning or blowing and should therefore be classified as foreign material. (Natural size.)

FOREIGN MATERIAL.

The foreign material, including dirt, pieces of cob, other grains, finely broken corn, etc., as provided for in column 4 of Table I, should include not only material that will pass through the sieve with holes nine sixty-fourths of an inch in diameter, as shown in figure 6, but should also include the coarser foreign material, such as is shown in figure 7. It will be found after a little experience that the coarse material shown in figure 7 can be taken out very quickly by hand picking after the finer material has been removed by screening, whenever such hand picking is necessary to determine correctly the grade of the grain in question.

CRACKED CORN.

As provided for in general rule No. 9, all coarsely broken pieces of kernels that will pass through the metal sieve perforated with round holes one-quarter of an inch in diameter (first sieve) and are retained on the sieve with the smaller perforations (second sieve) shall be considered as "cracked" corn, as shown in figure 8. More-

over, this is the only broken corn which should be so classified in these grades. The finely broken pieces which will pass through the sieve with the smaller perforations should be classed with the foreign material, and the large pieces which remain on the sieve with the quarter-inch holes should be classed with the whole kernels.

FIG. 6.—Foreign material, including dirt, chaff, other grains, finely broken corn, etc., which will pass through the sieve with the smaller perforations, nine sixty-fourths of an inch in diameter. (Natural size.)

However, it is not intended that all material remaining on the sieve with the smaller holes shall be classed as "cracked" corn. All small whole kernels, such as those that are shown in figure 9, which will go through the sieve with the quarter-inch holes should be picked out after screening and classed as whole corn. Likewise, any "other grains," pieces of cob, or other foreign material remaining with the "cracked" corn on the sieve with the smaller holes should be picked out and added to the foreign material, dirt, etc. In applying these grades, no separation should be made of the sound and the damaged "cracked" corn, but the whole should be classed only as "cracked" corn.

FIG. 7.—Coarse material, which will not pass through the sieve with the smaller perforations, nine sixty-fourths of an inch in diameter, but which should be picked out of the sample and included with the foreign material, dirt, cob, other grains, etc. (Natural size.)

COLOR.

Color determinations should be made on not less than 100 grams of the screened sample; that is, after the "cracked" corn and foreign material have been removed. All grades of white corn require that at least 98 per cent, by weight, shall be white, as stated in general rule No. 2, and all grades of yellow corn require that at least 95 per cent shall be yellow, as provided in general rule No. 3. In most

cases, when examining white corn it will not be necessary to make weighings unless there are more than 5 kernels of corn of other colors, and on yellow corn, unless there are more than 12 kernels of

FIG. 8.—"Cracked" corn, consisting of pieces of kernels which will pass through the sieve with the quarter-inch perforations. (Natural size.)

other colors, in a 100-gram sample, as 5 kernels will usually be less than 2 per cent and 12 kernels less than 5 per cent.

More difficult problems arise, however, in dealing with special types or varieties of corn or with individual kernels, such as "straw-

FIG. 9.—Small whole kernels which will pass through the sieve with the quarter-inch perforations, but which should not be classed as "cracked" corn. (Natural size.)

colored," "red-cast" yellow, etc., which are difficult to classify. At most, such classifications can be only arbitrary and in keeping with the best commercial practices. In order to bring about the greatest uniformity of application, some of the more important types of kernels from the standpoint of color are shown in Plate I in natural

colors, as nearly as it is possible to reproduce them. Kernels numbered 1 to 9, inclusive, under types of color, have been classified as white corn. It will be noted that some of the kernels at the right in this first series are of a very light straw color, but not sufficient to justify their being classed as of other colors when found in a grade of white corn. Kernels with a tinge of pink over white (not shown in the plate) should be considered on the same basis as straw-colored kernels; that is, where the pink color is only very slight they may be classed as white; otherwise they should be eliminated. In kernel No. 10, however, the yellow color is more pronounced, and such kernels should not be classed as either white or yellow corn. The same is true with all kernels numbered 10 to 18, inclusive. Kernels numbered 10 to 14, inclusive, are intended to represent white-capped pale yellow, kernel No. 19 represents a pale yellow of the lowest type, and kernel No. 27 represents a "red-cast" yellow of the most pronounced type which should be classed as yellow corn.

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BULLETIN OF THE U.S. DEPARTMENT OF AGRICULTURE

No. 169

Contribution from the Bureau of Plant Industry, Wm. A. Taylor, Chief.
February 20, 1915.

PROFESSIONAL PAPER.

INJURY BY DISINFECTANTS TO SEEDS AND ROOTS IN SANDY SOILS.

By Carl Hartley, *Pathologist, Investigations in Forest Pathology.*

INTRODUCTION.

For several seasons the writer has conducted experiments in the application of disinfectants to pine seed beds for the purpose of controlling damping-off. Formaldehyde and various inorganic acids and salts have been tested. The work conducted at two of the nurseries with seed beds sown in the spring and summer has now been completed. The practical results of the disease-control work have already been briefly summarized.[1] Because of the interest of soil investigators as well as plant pathologists in the behavior of disinfecting agents in the soil, the data on injury to pine and weed seedlings by disinfectants are here published separately. Data on the effects of the disinfectants on the growth rate of pine seedlings are still being gathered from three nurseries, and it is hoped to publish these later.

Acknowledgments are due Dr. F. K. Cameron and others, of the Bureau of Soils, and Drs. Rodney H. True and F. D. Heald, of the Bureau of Plant Industry, for helpful suggestions.

SOIL CHARACTERS.

The nursery where most of the work was done is at Halsey, Nebr., in a valley among sand hills. The soil throughout the nursery area is quite uniform, both soil and subsoil being classed as fine sand. There is a fair amount of humus in the upper 10 to 12 inches, in some places extending to nearly 20 inches below the surface. Below 12 inches there is no humus in most of the nursery. The soil at the other nursery, that of the Pennsylvania Railroad, near Morrisville, Pa., is a light-gray sandy loam, with a fine, reddish, sandy subsoil which is rather nearer the surface than the subsoil at Halsey. Exami-

[1] Hartley, Carl, and Merrill, T. C. Preliminary tests of disinfectants in controlling damping-off in various nursery soils. *In* Phytopathology, v. 4, no. 2, p. 89-92, 1914.

nation by the Bureau of Soils of the United States Department of Agriculture shows the presence of the usual soil-forming minerals. The chemical and mechanical analyses are given in Table I.

TABLE I.—*Chemical and mechanical analyses of the nursery soils at Halsey, Nebr., and Morrisville, Pa.*

[The soil samples were taken from the upper 6 inches; subsoil from depths of 15 inches at Halsey and 12 inches at Morrisville.]

Analyses.	Percentage of soil.		Percentage of subsoil.	
	Halsey.	Morrisville.	Halsey.	Morrisville.
Chemical constituents:				
MnO	0.24	0.21	0.18	0.19
Fe_2O_3	3.08	1.60	2.85	1.30
Al_2O_3	14.93	8.72	14.95	6.20
K_2O	4.48	1.68	.80	1.88
P_2O_5	Trace.	Trace.	.48	.11
CaO	.86	2.23	3.79	1.35
Total salts by bridge	.21	.39	.09	.08
N	.07	.03	.09	.05
CO_2 (from carbonates)	None.	None.	None.	None.
Ignition loss (two determinations averaged)	2.41	2.93	.55	1.96
Lime requirements (CaO) per acre ... pounds	2,450	1,750	2,450	1,750
Mechanical constituents (size of particles):				
Fine gravel, 2 to 1 mm	0	1.0	0	0.5
Coarse sand, 1 to 0.5 mm	3.0	10.9	3.5	8.6
Medium sand, 0.5 to 0.25 mm	9.5	16.1	15.4	13.4
Fine sand, 0.25 to 0.1 mm	58.1	28.9	61.3	30.5
Very fine sand, 0.1 to 0.05 mm	21.0	19.2	17.5	23.5
Silt, 0.05 to 0.005 mm	6.5	18.5	1.5	18.1
Clay, 0.005 mm. and finer	2.1	5.5	.8	5.2

The wilting coefficient, determined by the indirect method of Briggs and Shantz,[1] was 3.42 per cent for the surface soil and 1.5 per cent for the subsoil at Halsey, and 4.92 per cent for the surface soil and 4.73 per cent for the subsoil at Morrisville. The samples examined from Halsey were taken from 10 different points in the nursery, while the samples from Morrisville represent three different points.

EXPERIMENTS AT HALSEY, NEBR.

Experiments at the nursery at Halsey have been carried on in cooperation with the United States Forest Service during the past five years. Mr. Robert D. Rands assisted the writer during the year in which most of the data were secured, and Messrs. R. G. Pierce and Fred R. Johnson, of the Forest Service, rendered material assistance in the work.

DISINFECTANTS USED.

Part of the sulphuric acid used in the following experiments was C. P. (chemically pure), but most of it was a clear commercial grade, the acid used in most of the work here reported having a specific gravity of 1.84 and that used for the latest work a specific gravity of

[1] Briggs, L. J., and Shantz, H. L. The wilting coefficient for different plants and its indirect determination. U. S. Department of Agriculture, Bureau of Plant Industry Bulletin 230, 1912.

1.83. Repeated parallel tests of C. P. and commercial sulphuric acid failed to develop any difference in their effect on the seed beds. A part of the hydrochloric and nitric acids used was C. P. and part commercial. The ammonia used was the strongest commercial ammonia water obtainable from local druggists (ordinarily 26° Beaumé). The formaldehyde used was the so-called 40 per cent commercial solution. Because of the need of distinguishing between pure formaldehyde and this commercial solution the latter will be referred to as formalin. The general use of the term "formalin" for the commercial solution appears to have become approved by custom,[1] despite the fact that this term formerly applied only to the product of an English firm. The lime-sulphur used was a commercial solution with a specific gravity of 1.31. The mercuric chlorid used was C. P. and the cupric sulphate was the fully hydrated crystalline form. The copper acetate was neutral, containing a single molecule of crystallization water. The zinc chlorid was a technical grade, granular, guaranteed from 95 to 98 per cent pure. All lime used was air-slaked.

The unit of measure used throughout is the fluid ounce (29.574 c. c.) for the acids, formalin, ammonia, and lime-sulphur solution, and the avoirdupois ounce (28.35 grams) for the other substances. Except where otherwise stated, all of the disinfectants were applied in aqueous solution. When lime was used the powder was spread dry on the surface of the bed and was worked into the upper 2 or 3 inches with a rake. Two or three pints of water per square foot of seed bed was found a convenient vehicle for applying the disinfectants. Because of the variable moisture content of the soil the degree of dilution of the solution before application is not of the greatest significance. The amount of the disinfectant used per square foot of soil surface is given in all cases as the measure of the strength of the treatment.

PLANTS UPON WHICH OBSERVATIONS WERE MADE.

The seed beds on which disinfectants were used were sown with different species of pine. Jack pine (*Pinus divaricata*) was the species used in most of the work, while western yellow pine (*P. ponderosa*), Norway pine (*P. resinosa*), and Corsican pine (*P. laricio*) were also used, the relative frequency being in the order named.

Weeds of various types appeared in the seed beds in addition to the pines, and data as to their tolerance of disinfectants were also obtained. Cryptogams were represented by a large-stalked species of Equisetum, the algæ conspicuous in many nurseries being present to but a slight extent. Monocotyledons were represented by various grasses, *Eragrostis cilianensis* [2] being much the most common, while *Echinochloa crus-galli*, *Panicum barbipulvinatum*,[2] and *Chaetochloa*

[1] Perkin, W. H., and Kipping, F. S. Organic chemistry, new ed., p. 124. London, 1911. See also Webster's New International Dictionary, 1913.

[2] Determinations made by Mr. P. L. Ricker.

viridis[1] were also more or less common. The nurserymen pulled up most of the weeds before flowering, so that it was not possible to determine positively the relative frequency of the different grass species for each plat. The commonest dicotyledons were *Mollugo verticillata*,[1] *Portulaca oleracea*,[1] *Amaranthus retroflexus*,[1] *A. hybridus*,[1] *A. graecizans*,[1] *A. blitoides*,[1] and *Euphorbia glyptosperma*.[1]

INJURY TO PINES BY SULPHURIC ACID APPLIED AT OR AFTER GERMINATION.

In the following cases sulphuric acid was applied to the beds after some pine seedlings had come up. Because of the great irregularity of germination in many beds the time of germination can be given only approximately. It represents as far as possible the date by which enough seedlings had appeared to constitute a fair stand. Most of the experimental plats were sown with jack pine. The results with this species appear in Table II.

TABLE II.—*Effect of sulphuric acid on seedlings of jack pine, at Halsey, Nebr.*

Number of plats treated.	Time of treatment.	Fluid ounce of acid per square foot.	Volumes of water.	Result.
4	On date of germination 6 days after germination	0.172 .086	128	All killed.
2	On date of germination 6 days after germination 8 days after germination 13 days after germination	.086 .043 .043 .043	256	Nearly all killed.
4	1 day after germination	.086	128	Many killed.
4	....do 3 days after germination 6 days after germination 8 days after germination 21 days after germination	.043 .043 .086 .043 .043	256	More killed than in preceding experiment.
2	On date of germination 2 days after germination	.021 .021	512	Germination, 11.8 per cent.
2	On date of germination 2 days after germination	.011 .011	1,024	Germination, 13.8 per cent.
2		None.		Germination, 14.7 per cent.

Half of the plats in Table II which were given the stronger solutions were sprinkled lightly with water immediately after each treatment. This watering had no evident effect in the plats treated with the 128-volume solution, but in four plats which received the 256-volume solution, followed by sprinkling, the stand of seedlings was more than twice as great as on four adjacent plats which were given the acid treatment only.

The results in the plats treated with the 512-volume solution indicate that a total of 0.043 ounce of acid per square foot applied before germination was complete was sufficient to prevent the appearance of some of the latest germinating seedlings, while 0.021 ounce in two applications had little or no effect. Further tests would be necessary to prove that injury can be caused by these very weak treatments.

[1] Determinations made by Mr. P. L. Ricker.

Acid was also used after germination on seed beds of western yellow pine. In the first test the percentage of the seedlings which died during the first 33 days after germination was determined for four plats, as follows:

Plat VIII–A.—On the twelfth day after germination, 0.086 ounce of acid in 128 volumes of water; repeated on the fourteenth and nineteenth days. Loss, 72 per cent.

Plat VIII.—Same acid treatment as VIII–A, but sprinkled lightly with water after each application. Loss, 33 per cent.

Plat 27.—On the sixth and sixteenth days after germination, 0.086 ounces of acid; 12, 14, and 19 days after germination, 0.043 ounce of acid; solution in 256 volumes of water. Loss, 21 per cent.

Plat 28.—No treatment. Loss, 23 per cent.

While the loss in plat 27 was slightly less than that in the untreated plat there is clear evidence that the acid killed the seedlings, as the parasitic loss in this plat was very much less than in the untreated plat.

The treatments on Plats VIII and VIII–A were practically duplicated on a seed bed 13 days younger, with the result that the losses for the first 20 days were 45 and 47 per cent, respectively, as compared with 16 per cent in the nearest check.

Further tests of sulphuric acid on germinating yellow pine were made during the two following seasons. In the first case, acid in 256 volumes of water was tested on beds which had received 0.188 ounce of formalin per square foot 40 days before sowing, a treatment which in itself had no appreciable influence. The results were as follows:

Plat 402–S.—Seven and again twenty-five days after germination, 0.125 ounce of acid. Germination, 64 per cent; loss after germination, 44 per cent.

Plat 402–N.—Seven days after germination, 0.125 ounce of acid. Germination, 51 per cent; loss, 30 per cent.

Check plat.—No acid. Germination, 68 per cent; loss, 62 per cent.

In this series, the effect of the acid was clearly to prevent the appearance of the latest germinating seedlings and to kill the youngest seedlings which had already broken through the soil. The heavier loss in the untreated plats is due to heavy parasitism, which the acid treatment almost entirely prevented.

The following season, using a solution of one part in 256 volumes of water, the following amounts of acid were applied to yellow-pine plats: 0.047 ounce per square foot on two plats three days after germination; the same amount on two other plats six days after germination; and 0.063 ounce on three plats seven days after germination. No noticeable injury occurred, though counts of the seedlings indicate that a few were probably killed by the acid.

Most or all of the injury caused by applications after the beginning of germination was due to injury to the roots. The light sprinkling with water just after acid applications, which in a number of

cases resulted in lessening injury, presumably exerted its effect through an immediate further dilution of the acid in the surface layer of soil. While part of the apparent freedom of the aerial parts of the plants from direct acid injury may be due to the slight tendency of liquids to adhere to pine seedlings, drops of 1 to 256 acid solution by volume (0.71 per cent by weight) frequently remained caught in the center of the whorls of cotyledons of yellow-pine seedlings. This localization of solution was not accompanied by any noticeable localized injury. The experience of Craig,[1] indicating direct injury to the foliage of grapes, plums, and apples out of doors by a solution containing but 0.25 per cent of the acid, was more closely duplicated in the case of seedlings of a grass resembling a common native species of Panicum, which occurred in some of the plats. Definite characteristic spots of dead leaf tissue were noted on the grass plants in a few cases in plats treated with a solution of 1 to 512 by volume (0.36 per cent). The solution adhering to the leaves is, of course, concentrated by evaporation of the water after application, so the injury from spraying with solutions is actually caused by a much stronger solution than that applied.

The tests outlined in the foregoing statement indicate that after the seed begins to germinate, any application of sulphuric acid sufficient to affect materially the activity of the damping-off parasites will cause the death of the radicles of some of the pine seedlings.

In applications after the beginning of germination, the concentration of the solution applied, as well as the amount of acid used per square foot, seemed distinctly related to the amount of injury to the roots of the seedlings. This indicates that the injury occurred very promptly after the application of the solution, before diffusion between the upper and lower layers of soil had time to equalize quantities and concentration of the soil solution. The younger parts of the roots were still in the upper 1 or 2 inches of soil in most cases at the time the injurious solutions were applied.

INJURY TO PINES BY SULPHURIC ACID APPLIED AT THE TIME OF SOWING.

In applications made at the time of sowing it was found that stronger treatments could be given without injury to the pines than when the treatments were delayed until germination. Stronger treatments were also required in order to control parasitic fungi, so that it was necessary in these tests also to work with treatments strong enough to cause injury to seedlings. Because of the numerous advantages of acid treatment at sowing, from the standpoint of disease prevention and nursery practice, a detailed study of the injury it causes to seedlings was undertaken with a view to prevention.

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[1] Craig, John. Effects of dilute sulphuric acid on foliage. *In* Canada Exp. Farms, Rpt., 1893, p. 101-102, 1894.

The procedure followed in treatment at sowing time was to (1) prepare the seed bed, (2) soak it with the disinfectant, (3) sow the seed broadcast, (4) cover with one-fourth inch of dry soil, and (5) apply the rest of the solution. The seed bed was not stirred up after the application of the solution was commenced. In no case in spring-sown beds has there been any indication that the treatments injured the pine seed before germination started, although the treatment, in strengths varying from 0.125 to 0.375 fluid ounce of acid per square foot, has been tested during the past three seasons in 19 different experimental series of jack pine, in 4 series each of yellow pine and Norway pine, and 1 series of Corsican pine. The proportion of germination in acid plats was nearly always higher than in the untreated plats (due to the prevention of parasites rather than to stimulation), and as high as in plats of soil disinfected by heat.

In jack-pine plats in which germination was reasonably prompt (12 to 14 days) and no special measures were taken to prevent injury to seedlings, many seedlings were killed or injured after germination began on plats which had received, respectively, 0.125 ounce and 0.141 ounce of acid per square foot at sowing, while 0.188 ounce per square foot always resulted in injury unless special protective measures were taken.

DESCRIPTION OF THE INJURY.

Injury to the seedlings in plats treated at or before the time of sowing took the form of damage to the growing apices of the radicles, with the result that extension of the root was stopped. Whether the meristematic apical cells were actually killed or simply lost their meristem qualities was not determined, though the former is the more probable. In most cases, root apices rendered incapable of growth retained their normal cream color for a few days after the injury and often recovered, though in severe cases they turned dark very soon. Plate I and text figures 1 and 2 show chemically injured seedlings. Plate I, figure 1, shows a healthy seedling, younger than the injured seedlings in figures 2, 3, and 4 of this plate, so that the darker color of the upper parts of the roots of injured seedlings is chiefly due to difference in age, rather than to the effects of the acid. The disproportionately short roots of the injured seedlings are especially noteworthy.

FIG. 1.—*Pinus divaricata* injured by acid. Root growth has just been resumed by two laterals after 11 days suspension. × 1⅓.

Ordinarily the growth of cells just back of the apex was not entirely prevented, so that the root tips became truncated as a result of the uneven growth. (Pl. I, fig. 2.) Distorted growth was also common. The capacity for absorption was usually retained by the injured roots for some

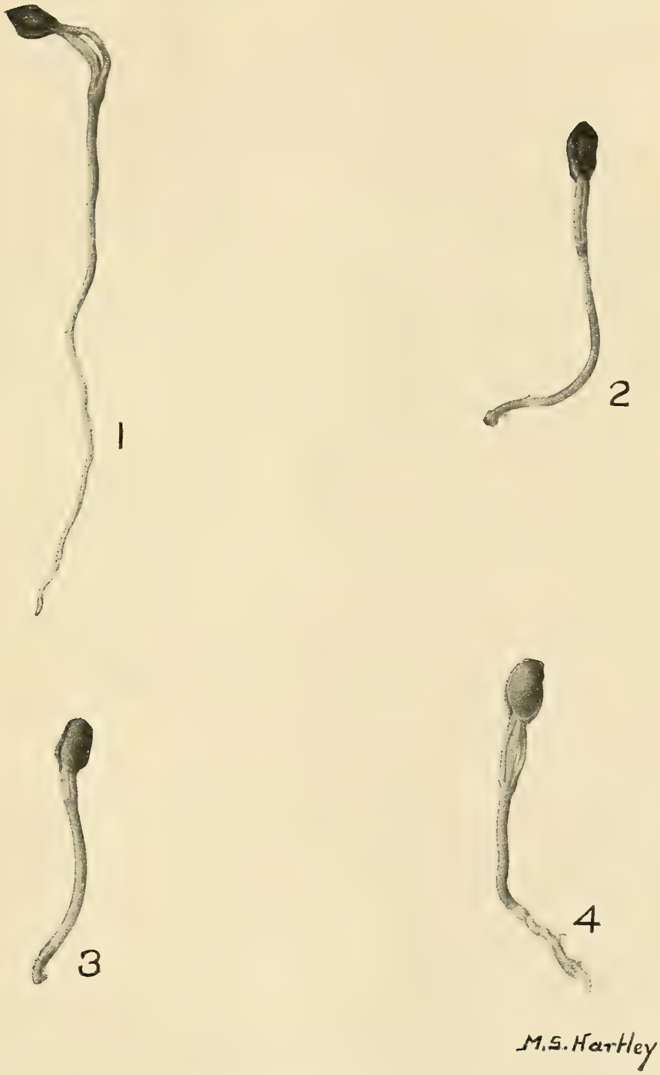
time. Although injury to root apices commonly took place before the seedlings appeared above the soil, most injured seedlings came up, and when the soil around the short root was kept moist the growth of the stem and leaves continued for some time at a normal rate. All of the development of the aerial parts of the seedlings shown in Plate I, figures 2, 3, and 4, was made after the extension of the root had been stopped by acid.

Injured seedlings ordinarily lived till the surface of the upper part of the root became brown and presumably impervious, as in the older parts of the root in healthy seedlings after two or three weeks. In the worst injured seedlings this root browning seemed to take place somewhat earlier than in healthy plants. The decrease in diameter which is noticed in the older parts of normal roots at the time of browning was seldom observed in acid-injured roots. Because the injured seedlings were not able to develop new root tissue, absorption ultimately became impossible and death from drought ensued. The seedlings shown in Plate I, figures 2 and 3, have practically reached this condition, though both still appeared to be growing normally when they were dug up. Plate I, figure 4, shows a seedling injured at the same time as that in Plate I, figure 3, which has recovered by recommencing root growth.

FIG. 2.—*Pinus ponderosa* injured by copper sulphate. Root growth has been resumed by a number of laterals. (Natural size.)

Where the roots of injured seedlings were very short, the plants died very soon, either because the soil was allowed to dry out to below the level reached by the short root or because the short root did not afford sufficient mechanical support for the top-heavy stem, and the seedling fell over or was washed out in watering. In the cases where injury was earliest, so that the radicle had scarcely emerged from the seed coat by the time its tip was killed, the seedlings failed to appear above ground at all.

In a good many cases seedlings which had extended their roots a centimeter or more before injury ultimately recovered, either because of a resumption of terminal root growth, as shown in Plate I, figure 4, or by laterals starting just back of the apex, as in text figure 1. In such cases the parts of the seedlings above ground at no time showed any effect of the acid, and the only way in which the existence of injury could be detected was by examining the roots. Renewal



HEALTHY AND ACID-INJURED PINE SEEDLINGS.

FIG. 1.—*Pinus divaricata*, healthy seedling. (×2.) FIG. 2.—*P. divaricata*, acid injured. (×2.) Probably not capable of recovery. The root growth was stopped before the seedling came up. The entire development of the stem and leaves above ground has taken place since the cessation of root growth. FIG. 3.—*P. laricio*, acid injured. (× 2.) Injured when so little root had developed that there was no possibility of a resumption of growth. Illustration made 10 days after the killing concentration occurred. FIG. 4.—*P. laricio*, acid injured. (×1½.) Recovering by terminal resumption of root growth, as shown by the white root tip.

of root growth in injured seedlings was most commonly observed from 8 to 12 days after the original cessation of growth. Dr. Perley Spaulding has advised the writer that a year prior to the observations here reported he found this resumption of growth by laterals in injured western yellow-pine seedlings in experimental plats at Burlington, Vt.

It is seldom possible to recognize acid injury immediately after occurrence. Even after death takes place it is not possible to distinguish the deeper rooted injured seedlings from those killed by parasites, as by the time the seedling gives indications of death above ground the roots are too badly decayed to show what caused death. The best way to detect acid injury is to dig up healthy-looking seedlings in different parts of a plat a week or ten days after the first seedlings come up. The roots of the seedlings will be found to have the following characters:

(1) Acid-injured seedlings (Pl. I, figs. 2 and 3). Length, one-fourth to five-eighths of an inch. Color, if brown at all, tip will be as brown as the rest; root firm throughout.

(2) Healthy seedlings (Pl. I, fig. 1). Length, 1 to 3 inches. Color, upper part may be brown, but tip will be white.

(3) Damped-off seedlings (attacked by parasites). Length, usually same as healthy, but lower part may be entirely decayed, making root appear short. Some part of root examined will always be found soft from decay, while acid-injured roots are firm throughout.

NOTE.—Care is needed to distinguish between the short root of an injured seedling and a healthy root which has been broken off short by accident. With a little practice, the difference between a root tip and a broken end can be easily recognized.

PREVENTION OF INJURY BY LEACHING.

The first attempt to prevent injury to germinating seedlings from the residue of acid applied at sowing was by leaching. To different plats in a bed which had received 0.188 ounces of acid at sowing three days earlier, 4, 8, 12, and 16 pints of water per square foot, respectively, were applied. The plats were thereafter given sprinklings equal to 0.3 of an inch of rain often enough to insure germination, which took place 11 days after sowing. The heaviest initial watering, equivalent to 3.2 inches of retained rainfall, prevented most of the injury which occurred on the other plats, but not all. The plat receiving but 4 pints (0.8 inch) suffered heavily, while the amount of injury in the 8 and 12 pint plats was intermediate. In a second test, with an acid treatment of 0.211 ounce at sowing, followed by germination in eight days, a 6-inch watering was given three days after sowing. The bed was purposely allowed to become quite dry on the day of germination, and later examination showed that a small number of the pines were injured. In a third test, this 6-inch watering was used on a bed which had received 0.313 ounce of acid. The bed was allowed to become somewhat dry 10 days

after the acid treatment (1 day before germination), and a number of seedlings were injured. It was evident from the results obtained that these heavy applications of water leached out enough acid materially to reduce acid injury. Leaching is evidently not practicable as a method of preventing injury at most nurseries when germination is prompt. In a sandy soil when the weather is cold and germination requires 18 or 20 days, leaching soon after the application of acid may be a practicable method of preventing injury.

PREVENTION OF INJURY BY FREQUENT WATERING.

Fortunately two definite relationships which opened the way for developing a practicable method of controlling the injury to the pines were found. It was found that the amount of water in the soil at the time of germination bore a direct relation to the amount of injury, and that injury seldom occurred after the seedlings had sent their roots down five-eighths of an inch into the soil. The length of root shown in Plate I, figure 3, is typical of injured seedlings in general. The stoppage of growth of root apices in treated beds always occurred at times when the upper soil became relatively dry and while the root tips of germinating seedlings were still in the upper five-eighths inch of soil. Although the nurserymen water the beds often enough to prevent drought injury to the seedlings, great variation in the moisture content of the surface soil occurs. The upper one-fourth inch of soil at this nursery just after watering has frequently been found to contain 21 to 25 per cent of moisture, while at the same points the soil when dry has contained but 1.96 per cent of water, the average of 12 determinations made on different occasions. In a single period of 11 hours the moisture content of the surface soil at four different points in the seed beds dropped from 12.02 to 1.85 per cent. This of necessity caused great variations in the concentration of the soil solution. While beds were not ordinarily allowed to become as dry as this during the germinating period, they often became quite dry at the surface. A little below the surface the moisture content of the soil is more stable. The most rapid loss of moisture found in the seed beds from 1 to 2 inches in depth during the period in which determinations were made was a drop from 17 to 11½ per cent in a period of approximately 36 hours. This explains the relative safety of roots which have penetrated below the upper half inch of soil. That the root above the tip should resist relatively high concentrations of acid is in agreement with the results of Heald [1] and other investigators, who find the tip of the root to be the portion most sensitive to poisons. The difference in resistance between the very

[1] Heald, F. D. On the toxic effect of dilute solutions of acids and salts upon plants. *In* Bot. Gaz., v. 22, no. 2, p. 130, 1896.

tip of the root and the tissue just back of it is well shown by the location of the new laterals developed by the seedling in figure 1.

In addition to the increased concentration of the acid solution already in the surface soil, due to the decrease of the solvent, acid from lower levels is presumably brought up to the surface by the capillary rise of the soil solution to replace that lost by evaporation. When the treated soil is soaked thoroughly with water and subjected to continuous evaporation for several days, but at a rate slow enough to avoid drying the surface soil entirely and breaking the capillary connection, this continuous upward movement of solution ultimately results in killing concentrations in the surface soil, even while it is still very moist. The problem of preventing injury to seedlings therefore becomes one of not only keeping the surface soil moist, but of maintaining a fairly constant downward movement of soil moisture, or at least of preventing a continuous upward movement for any considerable period, until after the roots of all seedlings have extended half an inch into the soil. Experience has shown that this can be done more easily with frequent light waterings than with heavier and less frequent applications.

A very few hours' delay in watering at a critical time has in some cases been enough to cause the killing of root tips by acid. Under certain conditions, as outlined in the foregoing paragraph, injury occurred before the beds appeared at all dry at the surface. Since appearances could not be relied on to show when watering was needed, systematic watering was tested. Furthermore, variation in individual judgment made necessary the use of measured quantities of water. Daily waterings equivalent to 0.4 of an inch of rain were not in all cases sufficient to prevent injury entirely. However, half this quantity applied twice as often, with the soil wet to begin with, was found sufficient to prevent all injury from moderate amounts of acid, even in very hot, dry weather. For large beds at this nursery which have received 0.188 ounce of acid at sowing, watering equivalent to 0.3 of an inch twice daily during the germination period has been recommended for summer use, so as to make certain that in the necessarily uneven large-scale work all parts of the bed will get at least 0.2 of an inch at each watering.

For work in cold spring weather, when the germination period is long, the expense of this special watering becomes considerable, and it further cools the soil to such a point that germination may be still more delayed. No such frequent watering is necessary to prevent injury in cool weather, but because of occasional hot, dry weather in early spring it is not safe entirely to abandon watering twice daily. A rather extreme instance of the variable temperature at Halsey was the rise of the temperature, as shown by a Weather

Bureau thermometer under a shelter 4 feet from the ground, from 37° F. at 8 a. m. to 98° F. at noon of the same day in April. The evaporation from white porous-cup atmometers set in the seed beds has varied from 14 to 59 c. c. for 24-hour periods 10 days apart, and still greater variations are to be expected from the darker soil surface. Hot, dry days increase the danger from acid injury both by increasing water loss and consequent acid concentration and by hurrying germination before the acid solution in the upper soil has had much time to decrease in strength. In view of the variability of weather conditions, the system now followed in preventing acid injury is to water daily in ordinary spring weather, every other day or even less often in misty or rainy weather, and twice daily when the temperature exceeds 80° F. In clear weather, waterings are to approximate 0.3 of an inch, while in cold and cloudy weather 0.2 of an inch is to be used. This watering system has proved practicable, and has been entirely successful in preventing injury to pines from acid applied at the time of sowing.

RELATION OF STRENGTH OF TREATMENT TO EXTENT OF INJURY.

The degree of dilution of the sulphuric acid in applications at sowing had no apparent relation to the amount of injury likely to result to the seedlings; that is, if 0.25 ounce of acid per square foot was applied, it made no difference, so far as noticed, whether it was dissolved in 64 or 192 volumes of water. There was not a sufficient number of tests with this factor as an independent variable to establish an entire lack of relation, but it is quite certain that within the limits given the amount of water used in making up the solution is not an important variable.

The first results indicated a rather surprising lack of constant relation between the amount of acid used per unit of soil surface and the amount of injury. In an early test of varying amounts of acid, all of which caused considerable losses of seedlings, the final stands in the plats were as follows:

Series 501.—Jack-pine plats; all except the check plats were treated with acid at sowing.

Eight check plats untreated. Final stands ranged from 71 to 163 per square foot; average, 122.

One plat, 0.125 fluid ounce of acid per square foot at sowing. Final stand, 216.

One plat, 0.141 ounce of acid. Final stand, 118.

Two plats, 0.188 ounce of acid. Final stands, 191 and 143; average, 167.

Three plats, 0.234 ounce of acid. Final stands, 107, 110, and 80; average, 99.

Two plats, 0.250 ounce of acid. Final stands, 23 and 153; average, 88.

One plat, 0.313 ounce of acid. Final stand, 94.

Two plats, 0.375 ounce of acid. Final stands, 11 and 116; average, 64.

In this series, as in those reported in the remainder of this paper, the plats received weights of seed proportional to their area.

In this series the variation between individual plats is great. Especially in the cases of the 0.250-ounce and the 0.375-ounce plats the variation between plats given the same acid treatments is much greater than the average variation between plats given different treatments or between the untreated plats, which are subject to much heavier variation from the action of parasites than the acid-treated plats. However, the averages indicate a distinct increase in the amount of injury as the quantity of acid is increased. The great individual variation between plats with the same acid treatment is to be explained by two factors which were not controlled. In the first place, different plats germinated at somewhat different times. Some plats therefore had a much greater average root length than others at the time the killing concentrations of the soil solution occurred. This greater root length resulted in the sensitive tip being farther down in the soil, where the acid solution does not become as concentrated as in the soil at the surface. It may also have been true here, as found by McCool[1] in his work with barium, strontium, sodium, and ammonium, that the root tips of seedlings a few days old are less susceptible to injury than those of seedlings which have just germinated, so that the age of the seedlings may have been even more important than the location of the root tips in making the older seedlings more resistant. Furthermore, those with the longer roots were not only less likely to be injured but also had a better chance to recover. (Compare Pl. I, figs. 3 and 4.) A more important variable factor in causing different results in plats with identical acid treatments was the watering during the germinating period. While all plats were watered at the same time, no attempt was made in series 501 to secure special uniformity in watering, and some became drier than others. A later test of different amounts of acid was made with plats sprinkled with measured quantities of water twice daily during the germination period. Germination took place nine days after the plats were treated and sown. The results are given in Table III.

TABLE III.—*Relation of the amount of acid applied and the thoroughness of subsequent waterings to the death of pine seedlings on plats treated with sulphuric acid at the time of sowing.*

[Seedlings per square foot surviving 44 days after germination.]

Water per square foot.	Treatment (ounces of acid per square foot).		
	0.211	0.250	0.313
2 pints at each watering..........seedlings..	....	179	142
1.5 pints at each watering..........do....	281	151	91
1 pint at each watering..........do....	125	64	47

[1] McCool, M. M. The action of certain nutrient and nonnutrient bases on plant growth. N. Y. Cornell Agr. Exp. Sta. Mem. 2, p. 159-162, 1913.

The decrease in stand both with decreasing amounts of watering and with increasing amounts of acid was sufficiently consistent in this experiment to establish beyond a reasonable doubt the relationship, both of the amount of acid used and of the amount of watering done, to the acid injury. In the weakest acid plat with the intermediate watering, no appreciable injury occurred. Because of the variation in germination aside from the influence of acid, the results were not always quite as consistent as in this series, but no reason has been found to doubt the relation between the amount of acid and the extent of injury in beds treated at sowing.

INJURY TO PINES BY SULPHURIC ACID APPLIED BEFORE SOWING.

In treating beds with sulphuric acid to kill fungous parasites the attempt was made to evade toxic action on the seedlings by applying the acid a number of days before sowing. Jack pine was also used in most of these tests. In such cases the beds were ordinarily hoed and raked just before they were sown, so that the upper 2 or 3 inches of soil was well mixed after the acid was applied. In the plats treated at sowing there was the possibility that the injury was limited to the surface five-eighths of an inch of soil, simply because this layer of soil had acted as a trap for the acid, absorbing most of it at the time of application. In the case of plats treated before sowing there was no such possibility. The seeds were in most cases covered with about one-fourth of an inch of soil taken from the upper 1 to 1½ inches of the soil of a near-by area that had been given the same treatment as the plat sown. Considerable injury occurred in plats which received 0.25 and 0.375 ounce of acid nine days before sowing (20 days in all elapsing before germination), although the treated plats received approximately 1.6 inches of water five days after sowing, followed by 0.3 to 0.4 of an inch daily till after germination. The slight drying of the surface soil which resulted in the injury on these plats took place the first day after germination, 21 days after the application of the acid.

In another series, using the same species of pine, amounts of 0.281, 0.375, and 0.687 ounce of acid per square foot were applied 11 days before sowing, two plats receiving the latter amount. Four days after sowing, the plats were given approximately 1.6 inches of water, followed by waterings of approximately 0.3 to 0.4 inch on the sixth, eighth, ninth, tenth, and eleventh days from sowing. Germination took place on the eleventh day, 22 days after the application of the acid, and on the morning of this day the soil surface became somewhat dry, but not dry enough to cause appreciable drought injury in the nonacid plats. As shown by later examination of the length of the acid-injured roots, injury took

place at this time. It was most serious in the 0.375-ounce plat, mainly because it had become somewhat drier than the rest. Even the 0.281-ounce plat seemed more injured than the 0.687-ounce plats, which were not seriously affected. The activity of parasites, mostly, probably, *Pythium debaryanum,* in the soil in these plats during and after the time that this injury was occurring to the seedlings is a matter of some interest. The slight relationship between the amount of acid used and the amount of injury taking place in these plats 22 days after treatment emphasizes what has already been said as to the apparent equalization of strength of acid solutions of different original strengths in the soil as the concentration decreases.

Plats of jack pine which had been entirely killed by applications of 0.172 ounce of acid at the date of germination and 0.086 ounce six days later, 0.258 ounce in all, were resown with the same species 23 to 24 days after the first treatment, germination taking place 34 to 36 days after the first treatment. No serious injury occurred to the seedlings in this second sowing, though no special watering was given. Similar results were obtained with yellow pine in plats treated with 0.3 ounce of acid 39 days before sowing (50 days before germination), no serious injury occurring despite the entire lack of any special watering. In all cases, acid applied before sowing can be kept from causing injury quite easily by the watering methods used for beds treated at sowing. The tests indicate that if germination takes place at any time during the first month after 0.25 ounce of acid is applied to the beds it will be necessary to give more than the usual nursery watering during the germination period in order to insure freedom from injury to the seedlings. Though it is somewhat easier to prevent acid injury in beds treated several days before sowing, treatment at the time of sowing is so much more effective against the damping-off parasites that it is considered preferable.

RELATIVE RESISTANCE OF VARIOUS SPECIES OF PINE TO SULPHURIC ACID.

There was considerable difference in the amount of injury caused by similar acid treatments on different species of pine. Jack pine, as a rule, seemed most liable to serious injury, while yellow pine was least often damaged, and Norway and Corsican pines were intermediate. The resistance of yellow pine as compared with jack pine was especially evident in beds treated shortly after germination. Most of this apparent difference in resistance is due not to variations in the capacity of the root tips to endure acid, but to a difference in the rate of growth. Yellow pine has a seed approximately ten times as heavy as that of jack pine and sends its root down much

faster at the start. By the time a yellow-pine seedling breaks through the soil cover its root has gone down much farther into the soil than with jack pine at the same age, and the application of a disinfectant to the soil surface at this time is therefore much less likely to injure the yellow-pine root tip. When disinfectants are put on the soil at sowing, the root tips have not yet emerged from the seed, and yellow pine has no such distinct advantage over jack pine. There is still a difference in depth of planting, however, as yellow-pine seeds are usually covered deeper than those of jack pine and the root tips thus start at a lower level. The more rapid growth is also of some advantage in beds treated before germination, as injury occurs only at times of surface concentration. The root tips of yellow pine may get down far enough to avoid injury from a concentration which occurs before the tips of jack-pine roots have reached the safety zone. While yellow pine has been less often injured than jack pine by acid applied at the time of sowing, concentrations occurring while there was a large porportion of yellow-pine root tips in the surface soil have killed large numbers of seedlings. In one extreme case, in which 0.250 ounce of acid per square foot was applied 28 days before sowing and repeated at sowing, with germination following five to six days later, only two-thirds as many seedlings came up as in untreated plats, and of these over 90 per cent died, nearly all as a result of acid injury. On the whole, while yellow pine has been much less often injured by acid treatment, the evidence indicates little, if any, greater resistance of its root tips than that shown by jack pine.

Corsican pine shows injury in the same way as jack pine (Pl. I, figs. 2 and 3). It has a seed smaller than yellow pine, but still much larger than jack pine and producing a faster initial root growth. It therefore seems a little less liable to injury than jack pine, for the same reasons that yellow pine is less liable. Norway pine on the other hand, though having a larger seed than jack pine, makes a much slower initial root growth at this nursery. Its slightly longer germination period gives the acid more time for dissipation, but the indications are that the root tips of this species possess a slightly greater acid endurance than those of jack pine. Corsican and Norway pine have not been tested as much as the other two species, and the evidence obtained as to their relative resistance has less value.

INJURY TO MISCELLANEOUS PLANTS BY SULPHURIC ACID.

The watering given pine seed beds at the Halsey nursery resulted in the germination of great numbers of previously dormant weed seeds of the species listed on pages 3 and 4. These ordinarily began to appear a little later than the pines and continued to come up in con-

siderable quantities for the first two or three weeks, after which time the number which came up decreased.

Most of the data on the effects of sulphuric-acid treatments on weeds were obtained on beds treated at the time of sowing. The observations indicated marked differences between the species observed in their ability to grow in soil recently treated with acid. It was evident throughout that the pines were less easily injured than most of the weed species. On plats which received no special watering till after germination, 0.125 ounce and 0.141 ounce of sulphuric acid per square foot, respectively, at the time of seeding entirely prevented weed growth. The untreated plats in this series were fairly well covered with Portulaca and grass species and with a few plants of Amaranthus. At sowing in another series on a plat given very frequent watering, 0.125 ounce of acid failed to reduce perceptibly the number of common weeds. Another plat given the same treatment, which had also received 0.125 ounce of acid 13 days before sowing, showed entire freedom from weeds, with only partial injury to the pines. In repeated tests during successive seasons, treatments of 0.188 ounce of acid at the time of sowing regularly prevented practically all weed growth for the first three weeks after the germination of the pines. In some cases no weeds came up in treated beds until a month after the appearance of the pines. Beds treated with acid and so watered as entirely to prevent injury to the pines were nevertheless so free from weeds as a result of acid application that the cost of weeding the treated beds during the whole season has been only one-third that of untreated beds.

The appearance of Equisetum in acid-treated plats was of some interest. In an insufficiently watered acid plat on which the pines were seriously injured and on which not a single phanerogamic weed appeared, more Equisetum developed than in most of the untreated beds in the nursery. Equisetum was not a common weed anywhere, but it occurred more frequently in the acid beds than in the beds not treated.

The grasses throughout gave evidence of greater ability to endure the acid applied to the soil than did the dicotyledons. They were usually the predominant weeds and often the only ones in acid plats. This greater predominance of grasses over dicotyledons in the acid plats left little doubt as to their superior endurance of this treatment.

Unfortunately, few data were secured as to the factors which controlled the varying capacity of the different plants observed to endure acid applied to the soil. Most of the injury to the weeds did not occur in just the same way as to the pines. In the pines the commonest phenomenon was root injury, which allowed the seedlings

to come up, but caused them to die a few days later. With the weeds, nearly all that came up were quite certain to survive. The extent of the injury to weeds was shown chiefly by the small number of weeds which appeared on the acid plats as compared with the checks. The failure of seriously injured weed seedlings to appear above ground, as did most of the injured pines, may be due in part to a larger amount of stored food material in the pine seed and in part to a greater depth of soil over many of the weed seeds. It is barely possible that many still dormant weed seeds were killed at the time of the application of the acid. Some of the weed seeds in late-sown plats commence germination at or before the time of acid application, and are therefore probably killed at the time of application. The frequent occurrence of healthy Equisetum in beds where the acid killed the pines may be due entirely to the presence of old rootstocks and not to superior tolerance of acid. It has been suggested that the survival of grass where acid prevented the appearance of dicotyledons may be due to the branching habit of the grass roots, which makes injury to the tip of the primary radicle of less importance than with the plants which depend largely on a main taproot.

Despite the qualifications in the preceding paragraph it seems quite certain that a great many germinating weed seeds which were dormant at the time of the application of the acid and were deeper in the soil, and therefore exposed to lower concentrations of acid than the pines, were killed in much the same way as the pines by amounts of acid which would not injure the pines. The experiments indicate not only a distinctly greater tolerance for sulphuric acid in the pines than in the angiosperms most commonly represented in the beds, but within the angiosperms a somewhat smaller difference in tolerance between the grasses and dicotyledonous species was observed. Tests in water culture would be necessary to establish the differences in resistance of the various species observed in these experiments and to give the differences a quantitative value.

Treatments several days or weeks before sowing also had considerable effect on the number of weeds found in the seed beds during the first few weeks after the germination of the pines. The use of 0.3 ounce of acid 14 days before sowing, with sufficiently frequent watering after sowing to prevent injury to yellow pine, prevented the appearance of any dicotyledons for at least 43 days after treatment and allowed only a few grass seedlings near the edge of the plat and a couple of Equisetum plants. Mollugo, grass, and Portulaca seedlings were common in all the check plats in this series, and Amaranthus and Euphorbia were present, while Equisetum was at least no more common in the checks than in the acid plats.

In another series, in which watering was frequent enough to prevent injury to most pine seedlings, 0.25 ounce of acid nine days before sowing kept the plat free from all weeds except three grass plants for 1½ months, and 0.375 ounce applied at the same time prevented weed growth of any sort. While grasses predominated in the untreated plats, they also contained many plants of Mollugo, Portulaca, Amaranthus, and Euphorbia, their frequency being in the order named.

In another series watered in the same way, 0.281 ounce of acid 11 days before sowing and heavier treatments applied to three other plats at the same time entirely prevented weed growth till 47 days afterwards, while the checks contained the same species as those in the former series.

In series 519, plats A, C, and D (Table VI), 0.25 ounce of acid had a distinct effect on the weed flora, practically the same as 0.375 ounce, in plats examined 66 days after application.

In another series, watered quite frequently after sowing in order to prevent acid injury, acid applied 14 days before sowing the pines was tested. On adjacent plats the upper 6 inches of soil was partially sterilized at about the same time by heating in a moist condition to above 80° C. in an oven, all parts of the soil being brought to at least that temperature and kept there for not less than 10 minutes. The results are presented in Table IV.

TABLE IV.—*Weeds which appeared in plats disinfected by heat and by acid.*

Plat.	Treatment (ounces of acid per square foot).	Weeds found 42 days after treatment.
Four checks	None	60 to 100 per plat; grass commonest, Mollugo and Portulaca frequent, Amaranthus occasional.
J and K	Heated	Grass much as in checks, and making more vigorous growth; 2 or 3 Portulaca plants, and 1 Amaranthus in each plat.
C	0.25	5 grass seedlings, with several Mollugo near edge.
F	.375	5 grass, with 1 Portulaca and 1 Mollugo near edge.
G	.375	4 grass.
D	.5	3 grass.

Evidently, unless the grass seed survived a temperature of 80° C. or more, it had been blown into plats J and K after treatment, and migratory ability may explain part of its predominance over the dicotyledons in acid-treated plats. The results in general, nevertheless, indicate that it is somewhat more resistant to acid than the dicotyledons.

RELATION BETWEEN TIME OF APPLICATION AND AMOUNT OF INJURY.

The foregoing experience with pines and other plants in beds treated with acid at the time of germination, at sowing time, and at various times before sowing, shows clearly, as would be expected, that

the time of germination is when acid applied to the beds will do the most damage to pine seedlings. The longer the period before or after germination takes place that the acid is applied the less danger there is of acid injury. The free acid in the soil solution would normally be decreased by diffusion or leaching downward into the subsoil, by adsorption or solid solution by the soil, and by chemical interaction with other constituents of the soil or soil solution. No attempt has been made to determine the relative importance of these different processes in the removal of the acid from the solution. It has seemed rather surprising that even with applications of acid as small as 0.25 ounce per square foot enough acid remains free in the surface soil three weeks after application to kill the tips of jack-pine roots and prevent the growth of most dicotyledonous weed species for $1\frac{1}{2}$ months. In soil containing large quantities of carbonates there could be no such length of persistence of free acid.

The amount of injury occurring in plats treated at different lengths of time before germination and the comparative lack of relationship between the amount of acid used and the extent of injury in cases where more than 15 days elapse between treatment and germination indicate that the rate of dissipation of the free acid in the soil solution decreases rapidly as the concentration decreases. Very small amounts of acid have proved extremely injurious to root tips in the soil at the time of application. While they lose this extremely toxic character in a very few days after application, the final reduction to a point where no injury occurs requires a relatively long time. The apparent relative stability of very low concentrations of acid in the soil solution is in agreement with the general course of removal of a solute either by diffusion or chemical reaction.

ADDITION OF NEUTRALIZING AGENTS AFTER THE APPLICATION OF THE ACID.

In different experimental series, plats treated with sulphuric acid before sowing were later treated with neutralizing agents to prevent acid injury. This procedure greatly decreased the effectiveness of the acid treatment against the damping-off parasites on whose account the work was being conducted, and so it was not exhaustively tested. In no case was lime applied to the extent of equivalent weights of the acid used.

The indications are that injury to pines may be prevented by small amounts of lime put on the beds a few days after the application of the acid. The results of the treatments are given in Table V.

TABLE V.—*Injury to roots in plats treated with sulphuric acid 12 to 16 days before sowing and later treated with lime.*

Plat.	Treatment (per square foot).			Days from acid treatment to—		Excess of acid over lime (fluid ounce per square foot).[1]	Percentage of acid which lime should neutralize.[1]	Injury to pines.	Weeds present 1½ months after acid application.
	Fluid ounce of acid.	Pints of solution.	Avoirdupois ounce of $CaCO_3$.	Lime application.	Germination.				
Pinus ponderosa (series 504–E)	0.375	2	0.250	14	25	0.240	36	None.	Half as many as in check plats of same series.
P. divaricata (series 507): Five checks	None.	....	None.	......	......	......	....	....	Grass and Mollugo abundant; some Amaranthus, Portulaca, and Euphorbia in each plat.
M	.375	3	.250	6	20	.240	36	Slight.	Very few, mainly grass and Mollugo, but growth much more vigorous than in checks.
G	.500	2	.333	8	23	.321	36	None.	
K	.500	4	.333	9	24	.321	36	...do..	
P	.500	4	.200	7	22	.392	22	...do..	
E	.750	4	.333	7	22	.571	24	...do..	
L	.750	2	.500	7	22	.481	36	...do..	
O	.750	6	.500	7	22	.481	36	Slight.	
F	None..	....	.125	......	......	......	....	None..	More weeds than in untreated plats, in vigorous condition.
C	...do...	....	.250	......	......	......	....	...do...	
R	...do...	....	.375	......	......	......	....	...do...	
A	...do...	....	.500	......	......	......	....	...do...	
P. resinosa (series 514): Checks	None.	....	None.	......	......	......	....	....	Grass, Mollugo, Euphorbia, Portulaca, and Amaranthus.
J	.500	2	.333	5	24	.321	36	None.	Less than in checks; grass, Mollugo, and Euphorbia.
K	.500	4	.250	5	24	.365	27	...do..	Less than in checks; grass, Euphorbia, and Amaranthus.
N	None.	....	.500	......	......	......	....	...do..	As for check.

[1] Based on equivalent weights, assuming for the commercial sulphuric acid a maximum specific gravity of 1.84 and a purity of 95 per cent. No allowance is made for impurities in the lime.

It appears that at least in plats M and O the acid applied was not reduced to two-fifths of its original amount during the first six or seven days after application. The injury in plat M, with its acid excess of only 0.24 ounce, when compared with the lack of serious injury in other plats with a greater excess of acid (notably plat E, with an excess 2⅜ times as great), is a further indication of the relative stability of weak acid solutions in the soil.

In the case of series 514, acid injury occurred in a plat treated with a relatively small amount of hydrochloric acid, and it is quite certain that only the lime prevented injury in plats J and K.

Ammonia was also tested, following sulphuric acid. On jack pine, 0.750 fluid ounce of acid applied 21 days before sowing was followed a few days later by 0.469 ounce of the strongest commercial grade of ammonia. No injury to pines occurred. Watering in this series was very frequent, so injury might have taken place with ordinary watering despite the lime used. In series 514, a red-pine plat treated with 0.562 ounce of acid 13 days before sowing, followed by

0.5 ounce of ammonia eight days before sowing, suffered no injury. In this case the heavy acid treatment would probably have resulted in injury had not the ammonia been applied.

From the practical standpoint, the prevention of injury from acid in pine seed beds by the use of neutralizing agents at this nursery is not a success, because beds so treated are often as badly infested by parasites as beds which have received no disinfectant treatment. The action of heavy applications of lime on the beds is also somewhat in question. Amounts up to 0.5 ounce per square foot, as used in the neutralizing work, have, however, been used alone without any bad effect. In one case 0.73 ounce per square foot (equivalent to 1 ton per acre) used on jack-pine beds at or before seeding in two different series was followed by a serious decrease of germination, and in the other case by a marked increase in the number dying after the seedlings came up. Whether the effect was a direct injury to the seedlings or a stimulation of the parasites which attack them was not determined.

The effect on weeds of acid followed by lime is also shown in Table V. Much injury to weeds occurred despite the neutralization several days later of two-fifths of the acid applied. However, it is quite certain, especially in the case of series 504, plat E, that much more injury would have occurred had not the lime been applied. Three-fourths as much acid applied to another plat in this series at about the same time, and not followed by lime, prevented the growth of angiosperms on the plat. The extremely rapid growth of the weeds on the acid-lime plats a few weeks after the application of the lime indicates that most of the remaining acid had been broken down by the lime. If enough lime had been used to neutralize one-half or three-fifths of the acid applied, it is entirely probable that all of the acid remaining at the time of the lime application would have been broken down and the soil rendered entirely safe for sowing any crop plant desired. Because the lime applied was not sufficient to take up at once all the acid remaining in the soil at the time of application, as indicated by the injury to the pines in series 507, plats M and O, the question as to whether the acid prevented weed growth largely by killing dormant seed or entirely by killing germinating seed, as with the pines, remains undecided.

Ammonia, 0.469 ounce per square foot, was used in 3 pints of water a few days after the application of 0.750 ounce of acid, with watering sufficient to prevent injury to jack pine even on unneutralized acid plats. Examination approximately 45 days after the ammonia application showed an entire absence of weeds on the acid-ammonia plat, as on the acid plats, while the four checks all contained plants of grass, Mollugo, Amaranthus, and Portulaca. For 37 days after the ammonia was applied 0.562 ounce of acid followed by 0.5 ounce of ammonia five

days later resulted in preventing most weed growth, but not all. Ammonia alone, 0.5 ounce per square foot, had no effect on the weed stand 65 days after application.

TESTS OF MISCELLANEOUS DISINFECTANTS.

Tests were also made with disinfectants other than sulphuric acid. These are summarized in Table VI, together with enough sulphuric-acid tests to afford a basis for comparison. Because a plat can be directly compared only with the others sown at the same time, the plats are grouped by series rather than by disinfectants.

TABLE VI.—*Injury to pines and weeds by miscellaneous disinfectants.*

Plat.	Disinfectant.			Days from treatment to—		Injury to pines.	Weeds present in plats.
	Substance used.	Per square foot.		Sowing.	Weed examination.		
		Ounces.	Solution.				
			Pints.				
Pinus divaricata:[1] 60	Copper carbonate (basic). Ammonia	0.017 .275	1.4	......	......	Germination reduced to less than one-sixth of that in checks. Nearly all seedlings which came up were severely injured.	
62	Sulphuric acid	.172	1.4	0	......	Injury not serious.	
64	...do	.257	1.4	0	......	...do	
P. ponderosa:[1] 415[2]	Formalin	.25	2	0	......	Germination reduced to less than one-quarter that on other plats. No death due to disinfectant after germination.	
416[2]	...do	.125 .125	2 2	29 0	......	None.	
P. divaricata:[1] Series 501 (8 checks).	None	......	......	......	......	......	Portulaca and grass abundant;[3] *Amaranthus retroflexus* common.
J	Hydrochloric acid.	.188	2	0	30–31	None	One-half or two-thirds as many as in checks.
C	Nitric acid	.375	3	0	30–31	Slight or none	Grass rare; Portulaca, 2 or 3 plants.
B	Sulphuric acid	.125	2	0	30–31	Slight	None.
D	...do	.141	1.5	0	30–31	Moderate to heavy.	Do.
H	...do	.188	2	0	30–31	Moderate	A single trifoliate legume.
L	...do	.25	2	0	30–31	Very heavy	None.
P. ponderosa:[4] Series 504 (5 checks).	None	......	......	......	......	......	Mollugo, grass, and Portulaca abundant; Amaranthus and Euphorbia frequent.
L	Formalin[5]	.562	3	14	43	None	Half as many as in checks, mainly grass.
A	Sulphuric acid	.281	2	14	43	...do	Grass, at edge only; Equisetum, 2 plants.
C	...do	.188	3	0	29	...do	Grass, 2 plants.

[1] Watering as in ordinary nursery practice.
[2] Germination exceptionally rapid.
[3] "Abundant" indicates usually 100 or more plants per plat; "frequent" indicates 20 or more; "common" indicates intermediate numbers. All plats measured 2 by 4 feet.
[4] Watering very frequent.
[5] Plats covered tightly for 3 days after treatment to prevent too early evaporation.

TABLE VI.—*Injury to pines and weeds by miscellaneous disinfectants*—Continued.

Plat.	Disinfectant.			Days from treatment to—		Injury to pines.	Weeds present in plats.
	Substance used.	Per square foot.		Sowing.	Weed examination.		
		Ounces.	Solution.				
P. divaricata:[1]			*Pints.*				
Series 508 (7 checks).	None						Grass abundant; Mollugo, Portulaca, Amaranthus, and Euphorbia follow in the order named.
N	Formalin[2]	0.375	3	8	43–51	None detected.	Grass, 8 or 10 plants in each formalin plat; other species rare.
P	do	.375	2	8	43–51	None detected.	Grass, 8 or 10 plants in each formalin plat; other species rare.
M	do	.562	4.5	8	43–51	None detected.	Grass, 8 or 10 plants in each formalin plat; other species rare.
A	do	.75	3	14	43–51	None detected.	Grass, 8 or 10 plants in each formalin plat; other species rare.
D	do	.75	3	10	43–51	None detected.	Grass, 8 or 10 plants in each formalin plat; other species rare.
G	do	.75	3	6	43–51	None detected.	Grass, 8 or 10 plants in each formalin plat; other species rare.
H	do	1.00	8	14	43–51	None detected.	Grass, 8 or 10 plants in each formalin plat; other species rare.
L	do	1.00	4	14	43–51	None detected.	Grass, 8 or 10 plants in each formalin plat; other species rare.
U	Sulphuric acid	.25	2	9	43–51	Moderate	Grass, 3 plants.
S	do	.375	2	9	43–51	do	None.
Series 512[3] (5 checks).	None				47–48		Mollugo, common; grass, Portulaca, Amaranthus, and Euphorbia follow in the order named.
K	Hydrochloric acid.	.25	2	10	47–48	None	Grass, a dozen or more plants; Portulaca and Euphorbia still less abundant.
F	do	.375	3	10	47–48	Very slight	Grass, 16 plants; Portulaca, 2; Euphorbia, 2.
D	do	.562	3	10	47–48	Slight to moderate.	Grass, 4 plants; Portulaca, 2; Mollugo, 1.
A	do	.75	4	10	47–48	do	Grass, 6 plants; Portulaca, 2.
C	Nitric acid	.75	3	10	47–48	Moderate	Grass, 4 plants; unknown, 1.
G	do	1.00	4	10	47–48	Very slight	Grass, 3 plants.
N	Sulphuric acid.[4]	.281	3	11	47–48	Very heavy	None.
P	do	.375	4	11	47–48	Heavy	Do.
M	do	.688	5.5	11	47–48	Moderate	Do.
J	do	.688	2	11	47–48	do	Do.
Series 514[5] (5 checks).	None						Grass abundant, followed by Mollugo, Euphorbia, Portulaca, and Amaranthus in the order named.
F	Hydrochloric acid.	.75	2	13	42	None	Grass, 14 plants; Mollugo, 3 or 4.
G	do	.75	4	13	42	Slight	Grass, 11 plants; Mollugo and Euphorbia, several plants around edge of plat.
A	Sulphuric acid	.125 .125	1 1	13 0	42	Heavy; ⅓ affected.	None.
C	do	.188 .188	2 2	13 0	42	Heavy; ½ affected.	Do.
D	do	.25 .125	2 2	13 0	42	do	Do.

[1] Watered daily, 0.3 to 0.4 inch.
[2] Plats covered tightly for 3 days after treatment to prevent too early evaporation.
[3] Watered daily; dry at surface on date of examination.
[4] This plat became extra dry at time of germination.
[5] Watered daily, 0.15 to 0.3 inch, until 3 days before germination. Surface dry at that time; watering done twice daily thereafter.

TABLE VI.—*Injury to pines and weeds by miscellaneous disinfectants*—Continued.

Plat.	Disinfectant.			Days from treatment to—		Injury to pines.	Weeds present in plats.
	Substance used.	Per square foot.		Sowing.	Weed examination.		
		Ounces.	Solution.				
P. resinosa—Continued.			*Pints.*				
K	Sulphuric acid; Air-slaked lime.	0.50; .25	4;	13; 8	42	None	Grass, 15 to 20 plants; Euphorbia and Portulaca, 1 or 2 each.
P	Copper acetate; Air-slaked lime.	.281; .25	3;	12; 8	42	Slight or none	Same abundance as in checks, but in much less vigorous condition.
Series 516[1] (2 checks).	None	......	......	......	......	......	Grass abundant, followed by Mollugo, Portulaca, and Euphorbia in the order named.
A	Hydrochloric acid.	.562	3	0	28	(2)	Grass, 4 plants.
C	Nitric acid	.562	3	17	45	None	Grass, 12 plants; Mollugo, nearly same number.
D	Sulphuric acid	.188	2	0	28	....do	Grass, 2 plants.
F	....do	.281	3	0	28	....do	None.
Series 518[3] (6 checks).	None	......	......	......	......	......	Grass abundant, strongly predominating; Mollugo, Portulaca, Amaranthus, and Euphorbia follow in the order named.
J	Formalin[4]	.375	3	17	45	None	Grass, 14 plants; Mollugo, nearly as many; Amaranthus, 2 or 3.
K	....do	.562	3	17	45	....do	Grass and Mollugo, a dozen plants; Amaranthus, 2.
M	....do	1.00	4	17	45	....do	Grass, 4 or 5 plants; Mollugo, 4.
C	Mercuric chlorid.	.063	2	17	45	....do	Grass frequent.
D	....do; Sodium chlorid.	.063; .188	2	17	45	....do	Grass, 5 or 6 plants; Mollugo, 1; Amaranthus, 1.
A	Mercuric chlorid.; Air-slaked lime.	.094; .094	3; 0	17; 13	45	....do	Nearly as many as in nearest checks, but larger proportion of grass than in check.
N	Zinc chlorid	.281	3	17	45	....do	Grass, 4 plants; Mollugo, 1.
G	Copper sulphate.	.188	3	17	45	Slight, or none	Grass, 9 plants; Mollugo, 2.
P	Hydrochloric acid.	.375	2	0	28	None	Grass, 10 or 12 plants.
F	Nitric acid	.562	3	17	45	....do	More grass than in P; Mollugo and Amaranthus also present.
Q	Sulphuric acid	.125	2	0	28	....do	Practically the same as in nearest check.

[1] Watered 0.3 inch twice daily.
[2] A little at a margin missed in watering.
[3] Watered 0.3 inch, usually twice daily; surface of plats never allowed to become dry.
[4] Plats covered tightly for 3 days after treatment to prevent too early evaporation.

TABLE VI.—*Injury to pines and weeds by miscellaneous disinfectants*—Continued.

Plat.	Disinfectant.			Days from treatment to—		Injury to pines.	Weeds present in plats.
	Substance used.	Per square foot.		Sowing.	Weed examination.		
		Ounces.	Solution.				
P. divaricata:[1]			*Pints.*				
Series 519 (6 checks).	None						Mollugo very abundant, followed by grass, Amaranthus, Portulaca, and Euphorbia in the order named.
F	Ammonia[2]	0.5	2	34	66	Record lost	As in checks.
U	Mercuric chlorid.	.063	2	0	32	(3)	None.
V	....do; Sodium chlorid.	.063; .188	2	0	32	All seed killed	Do.
R	Lime-sulphur	.313	2	0	32	Three-fourths of the seed killed by unknown factor.	Records lost.
S	....do	.75	2	0	32	Germination good.	None.
L	Ferrous sulphate.	.5	2	0	32	Record lost	Nearly as many as in checks.
K	Cupric sulphate.	.281	3	34	66	Moderate to heavy.	Do.
P	Hydrochloric acid.	.562	3	0	32	Very heavy	Grass, very few plants at edge of plat.
M	Nitric acid	1.125	3	34	66	Record lost	Do.
O	....do; Sulphuric acid	.188; .125	1; 1	34; 0	32	Very slight	Do.
C	....do	.25	2	34	66	Record lost	Grass and Mollugo, each 7 or 8 plants; Amaranthus, 1.
D	....do	.25	3	34	66	....do	Grass, 3 plants.
A	....do	.375	3	34	66	....do	Grass, 7 or 8 plants.
H	Heat, 80° C. or greater for not less than 10 minutes.	(4)		Few	32	None	Grass, 7 or 8 plants; Portulaca, 1 or 2.
G	....do	(5)		Few	32	....do	Same as for H.

[1] Watered 0.3 inch, twice daily.
[2] Plats covered tightly for 3 days after treatment to prevent too early evaporation.
[3] Nearly all seed killed; heavy injury to those which germinated.
[4] Upper 2½ inches of soil heated.
[5] Upper 6 inches of soil heated.

DISCUSSION OF MISCELLANEOUS DISINFECTANTS.

HYDROCHLORIC AND NITRIC ACIDS.

Hydrochloric and nitric acids were used in series 501, plats C and J; 512, plats A, C, D, F, G, and K; 514, plats F and G; 516, plats A and C; 518, plats F and P; and 519, plats M, O, and P (Table VI). Injury by them seems to take place in just the same way as that caused by sulphuric acid, and the injured seedlings presented the same appearance as those injured by sulphuric acid. (See Pl. I, figs. 2 and 3.) Pine seeds were not killed by the amounts used at sowing, but the apices of the radicles in some plats were killed by the acid residue in the surface soil after germination began. Injury may be prevented, as with sulphuric acid, by waterings sufficiently frequent to prevent the concentration of the acid in the surface soil.

Volume for volume, the hydrochloric and nitric acids used did not seem to differ greatly in their effect on the pine seedlings or weeds, the hydrochloric acid appearing rather the more dangerous. The tests offer little opportunity for direct comparison. As with sulphuric acid, pines were less injured than weeds, and the grasses present seemed more resistant than the dicotyledons. The difference in the effect on jack pine, grasses, and *Mollugo verticillata* shows especially well in series 512 and 519, in whose checks Mollugo was the most common weed.

The tests show clearly the low toxicity of these acids in this soil as compared with sulphuric acid, volume for volume. Comparison of plats C and J of series 501 with plats B, D, and H in the same series indicates that sulphuric acid is three or more times as dangerous to both pines and weeds as nitric acid and much more dangerous than hydrochloric acid. In series 512, sulphuric acid seems two or three times as active against the pines as the other two acids, while the disparity in the action on weeds appears still greater. In series 516, results in plats A and D treated at the same time indicate that sulphuric and hydrochloric acids are equally toxic to the weeds when the amount of hydrochloric acid used is three times the amount of sulphuric. In series 518, plats P and Q, 0.375 ounce of hydrochloric acid per square foot appeared considerably more active against weeds than 0.125 ounce of sulphuric acid used on the adjacent plat. Weight for weight, the disparity between the two acids is much less. While the strengths of the acids used were not determined, a statement of the amounts used indicating relative concentrations of ionic hydrogen would have further decreased and might have entirely obliterated the apparent disparity in action between the three acids, as was found by Kahlenberg,[1] True,[2] and Heald [3] in their work with these acids in water culture. For instance, using for comparison sulphuric acid containing 90 per cent H_2SO_4 and making no allowance for impurities, nitric acid containing 60 per cent HNO_3 would contain, volume for volume, but 43 per cent as much ionic hydrogen, and 30 per cent hydrochloric acid but 31 per cent as much, assuming equally complete dissociation in the dilute solutions of the three acids.

TOXIC SALTS.

Copper sulphate, tested only twice, gave rather contradictory results. In series 518, plat G (TableVI), 0.188 ounce per square foot 17 days before sowing caused little or no injury to pines and consid-

[1] Kahlenberg, Louis, and True, R. H. On the toxic action of dissolved salts and their electrolytic dissociation. *In* Bot. Gaz., v. 22, no. 2, p. 81–124, 1896.

[2] True, R. H. The toxic action of a series of acids and of their sodium salts on Lupinus albus. *In* Amer. Jour. Sci., ser. 4, v. 9, no. 51, p. 183–192, 1900.

[3] Heald, F. D. On the toxic effect of dilute solutions of acids and salts upon plants. *In* Bot. Gaz., v. 22, no. 2, 1896, p. 130.

erable injury to weeds, while in series 519, plat K, an amount 50 per cent greater, 34 days before sowing, with more frequent watering, caused considerable injury to pines and had little effect on weeds. Copper sulphate injured pines just as did the acids, by stopping elongation of the radicles shortly after they emerged from the seed. Recovery took place in many cases. A marked case of the production of laterals in recovery from copper-sulphate injury is seen in a seedling taken by Dr. T. C. Merrill from a bed in a similar soil at Garden City, Kans., which had been treated heavily with copper sulphate at sowing and again after germination (fig. 2). Normal yellow pine at this age should have a single straight taproot going down at least five times as far as the one figured and with relatively little development of laterals. Ferrous sulphate (series 519, plat L) gave little evidence of toxic action in the soil as compared with other substances used. Further tests are necessary to give comparable data as to the behavior of copper acetate in the soil and the effect of lime in preventing injury by copper salts, the test made (series 514, plat P) being insufficient. The results in series 518, plat N, indicate that zinc chlorid is as dangerous to weed roots in this soil as copper sulphate, or slightly less dangerous.

Mercuric chlorid in the amounts used acts differently from any of the substances previously mentioned, in that it kills dormant pine seed in the soil at Halsey at the time of application. In series 519, plat V (Table VI), the seeds which failed to germinate were taken out of the soil and carefully examined, both with a hand lens and with a compound microscope. No indication was found that they had ever commenced germination. The difference is presumably due to greater penetrative power. Mercuric chlorid in the soil is injurious both to the roots of seedling pines and to weeds in quantities, which in the case of the other salts tested would have no effect. The addition of common salt to the mercuric chlorid at the time of application appears to increase the damage it does in the soil, possibly by delaying the entire breaking down of the disinfectant until it has time to act on the plants. (Compare 518–C and 519–U with 518–D and 519–V.) The additional toxic effect could hardly have been directly due to the 0.188 ounce of common salt per square foot applied, since 0.2 ounce of salt per square foot applied dry to a jack-pine bed three or four days before sowing in an earlier series had no effect on the pines or on the grass and Mollugo common in the series. The addition of sodium chlorid also makes the disinfectant more convenient to work with by greatly increasing the rapidity of solution. The addition to series 518, plat A, of an amount of air-slaked lime equal in weight to the mercuric chlorid applied four days earlier prevented most of the injury to weeds which occurred with smaller amounts of the chlorid in plats not limed.

With these salts, as with the acids, the pines appeared on the whole more resistant to toxic action than the angiosperms present. There was less evidence in the experiments of a difference in susceptibility to salts in general between the grasses and the dicotyledons. Heald's tests of the resistance of corn and peas to copper salts [1] showed for these plants a reversal of their relative resistance to acid, the peas being able to grow in twice as strong copper solution as corn, whereas with four mineral acids they could grow in solutions only one-fourth as strong.

Ammoniacal copper carbonate was also used with jack pine. A plat of this pine was given a solution made up of 0.006 ounce of copper carbonate and 0.099 fluid ounce of ammonia per square foot the first day after germination, and this was repeated two days later. Eight days after germination the plat was again treated, using 0.014 ounce of carbonate and 0.22 ounce of ammonia per square foot. Practically all the seedlings were killed by these treatments. Most of the injury appeared to be done by the first two applications, in which a total of 0.012 ounce of carbonate per square foot was applied. This plat, which received a total of 0.026 ounce of copper carbonate, was resown 16 days after the last application. No serious injury occurred to the second sowing.

Another plat treated just before sowing (plat 60, Table VI) further indicated a very great toxicity for ammoniacal copper carbonate if only the amount of copper contained is considered. The injury to pine in this plat was much more severe than in plat 64, which had been treated with sulphuric acid more than 25 times the weight of the copper carbonate used on plat 60. It is probable that the extremely toxic action of this fungicide was due more to the action of the ammonia than to the copper. The known tendency of ammonia to prevent the precipitation of copper salts from solution may, however, result in more prolonged activity of the copper in this disinfectant than when simple aqueous solutions of copper salts are applied to the soil.

FORMALIN.

Like mercuric chlorid, formalin is capable of killing seed outright if applied at the time of sowing. In a test of yellow pine in which the disinfectant was applied at sowing (plat 415, Table VI) most of the seeds were killed before they gave any outward evidence of commencing to germinate. So far as could be learned, those which were able to start germination were uninjured. In plat 416 (Table VI), which received the same amount of formalin, half at the time of sowing and half at an interval of a month earlier, no injury could be detected. In all other cases, formalin was applied several days

[1] Heald, F. D. Op. cit., p. 152.

before sowing and did no perceptible damage to pines or pine seed. This was true even in series 508, plat G, in which 0.75 fluid ounce per square foot was applied six days before sowing and evaporation allowed for only three days before sowing. The effect of formalin on the weed stand seemed approximately equivalent to that obtained with one-half or one-third the volume of sulphuric acid. As the weight of H_2SO_4 per fluid ounce of acid used was at least four times as great as the weight of HCHO in the formalin, the formaldehyde appears rather more effective, weight for weight, in keeping down weeds. The radical difference in the type of action of the formalin against the pines renders impossible any direct comparison with acid.

LIME-SULPHUR SOLUTION.

The results in series 519, plats R and S (Table VI), are contradictory. Injury to pines from fairly heavy applications of lime-sulphur at the time of sowing can probably be prevented by sufficient watering during the germination period. The injury to weeds occurred despite heavy watering.

EXPERIMENTS AT MORRISVILLE, PA.

During the season of 1912, in pursuance of recommendations by the writer, tests with sulphuric acid were conducted by Mr. R. E. Lee, under the direction of Mr. John Foley, forester of the Pennsylvania Railroad, at the nursery near Morrisville, Pa. Sulphuric acid only was used. All treatments tested resulted in a decreased stand. The results of very weak treatments on beds given ordinary nursery watering are shown in Table VII.

TABLE VII.—*Evidence of injury to pines by sulphuric acid applied at the time of sowing, Morrisville, Pa.*

Plat.	Number of plats averaged.	Species.	Sowing to germination.	Acid per square foot.	Watering.	Final stand, taking average of checks as 100.	Decrease in stand apparently due to acid.
			Days.	*Fluid oz.*			*Per cent.*
Series 631	1	Pinus ponderosa	6 to 9	0.031	Only as in ordinary nursery practice.	91	9
	11	do	6 to 9	.042		95	5
	8	do	6 to 9	.083		90	10
Series 632	16	Pinus resinosa	9 to 10	.083		55	45
Series 633	21	Pinus strobus	16 to 21	.083		27	73
Series 634	7	Pinus sylvestris	7	.083		74	26
Series 635	17	do	9 to 12	.083		63	37
Series 636	7	Picea excelsa	11	.083		56	44
Series 637	14	Pinus sylvestris	8 to 10	.083		62	38
Series 638:							
A	1	do		.188		34	66
D	1	do		.25		26	74
C	1	do		.375		4	96
G	1	do		.188	0.15 inch, twice daily.	83	17
F	1	do		.25		53	47
J	1	do		.375		45	55

The relative resistance of *Pinus ponderosa* to the acid is probably due to its rapid growth, as at Halsey. The severe injury to *P. strobus* is rather surprising in view of the length of time which elapsed before germination. The consistent relation in series 638 between the decrease in stand and the amount of acid used and the evidently helpful effect of frequent watering leave no reasonable doubt as to the agency of the acid in causing the decreased stand. In all of the series except 631 the treated plats were uniformly poorer than the checks. In series 638, fewer seedlings appeared in acid plats than in the checks in all cases, the deficiency being greatest in the ordinary watering plats, and the amount of death just after the seedlings came up in the ordinary watering plats was very large. The amount of germination and early loss for the other series was not determined.

The evidence of the experiments at Morrisville as a whole shows that at this nursery the amounts of acid necessary to cause injury were much smaller than at Halsey.

GENERAL DISCUSSION AND CONCLUSION.

It is evident that the toxicity of disinfectants to the roots of plants in soil at Halsey, Nebr., varies greatly in response to a number of different factors. The amounts of water in different parts of the soil at different times and the movements of soil water, which result in concentrating the soil solution at particular points, must be considered, as well as the concentration of the solution applied. The depth of the root tips in the soil at the time of greatest concentration of the soil solution is also of prime importance, and the time of application is a very important variable.

In general, while it is evident that disinfectants do not act on plant roots in soil to the same extent as in liquid cultures, they seem to act in much the same way. If only the free poison in the soil solution is considered, it is doubtful whether a great difference in degree of toxicity can be found in soil and in liquid cultures. However, the activity of poisons in the soil solution should not be expected to equal their activity in pure water cultures. Antitoxic relations which have been found by various workers to exist between numerous substances in water cultures may be expected to exist between most disinfectants and various components of the soil solution. An investigation of antagonism between substances obtained in soil extracts and some of the substances used in soil disinfection should yield some interesting results. Most poisons are of necessity rather unstable substances, and even where leaching is prevented, as in pot experiments, and nonvolatile substances are used, the loss of free poisons from the soil solution by combination with soil constituents and by other absorptive processes is undoubtedly great.

That acid solutions, in fact, are much more toxic just after application is clearly shown by the experiments at Halsey. That the rapidity with which disinfectants are rendered inactive in the soil should vary greatly in different soils is to be expected, in view of the great differences which exist in both their physical and chemical constitution. However, examinations of soils by the usual methods of chemical and physical analyses and lime requirement and wilting-coefficient determination do not give much indication as to how sulphuric acid may be expected to behave in different soils. A soil with a low wilting coefficient may be expected to have a rather low average water content under field conditions and therefore to require small amounts of disinfectants to raise the soil solution to a killing concentration. Coarse texture indicates low absorptive power and a consequent small capacity for disinfectants without injury to roots. A high lime requirement may indicate soil acidity, but it may also be found in a nonacid soil which has high absorptive capacity.[1] Both on theoretical grounds and from the results obtained at Halsey with sulphuric acid and mercuric chlorid treatments followed by lime, the carbonates present should have a decided influence in preventing injury by acids, and probably by many toxic salts as well. Experiments are under way at several nurseries at which preliminary results indicated a distinct relation between determinable chemical and physical characters and the behavior of disinfectants. But between soils as much alike as those on which the foregoing experiments were conducted, the physical and chemical examination made gives no clue to any difference which can explain the different behavior of sulphuric acid on the two. Neither soil yielded CO_2 by the method employed in the examination by the Bureau of Soils. The surface soil at Morrisville contains more CaO, has a higher ignition loss, a higher wilting coefficient, and a lower lime requirement than the Halsey soil, all of which would seem to indicate a greater capacity for acid at Morrisville. The experiments show throughout that the reverse is the case. While the tests made at the two nurseries are not absolutely comparable, comparison of the plats of series 501 (Table VI), which received from 0.125 to 0.25 ounce per square foot, with series 631 to 637 inclusive (Table VII), in which from 0.031 to 0.083 ounce was used, indicates that at Halsey the amount of acid required to cause injury is three times that required at Morrisville. It seems probable, in view of the semiarid conditions at Halsey, that the Morrisville soil was more acid or less alkaline than the Halsey soil.

An attempt to get an indication of different reaction between the two soils a year after the samples were taken failed, both soils giving

[1] Cameron, F. K. The Soil Solution, the Nutrient Medium for Plant Growth, p. 65, footnote 1. Easton, Pa., 1911.

negative results with the potassium nitrate and iodin test outlined by Loew [1] and turning blue litmus red, the latter phenomenon likely indicating absorption rather than acid reaction for either soil.[2] Titration of extracts from fresh samples of these soils should give more indication of the real cause of the different behavior of acid at the two places. If difference in reaction of the two soils explains the different results, it is probable that the difference in capacity for disinfectants would be less marked or even reversed with such disinfectants as copper sulphate.

Further evidence of the failure of chemical analysis or physical characters to show what action disinfectants will have on roots in different soils is seen in the difference between the results in these nursery soils and the results obtained by Lipman and Wilson [3] with a soil described as sandy and having a chemical constitution showing no very radical differences from those reported in the foregoing. On this soil they found that there was no evidence of damage to either wheat or vetch seedlings by sulphuric acid in the amount of 600 parts per million of water-free soil applied several days before sowing. While these experiments, conducted in pots, can not be directly compared with those of the writer, it is sufficiently evident that the results are very different. At Halsey, 0.125 fluid ounce per square foot, followed by the ordinary watering given germinating seed beds, entirely prevented the growth for at least a month after application of the monocotyledonous and dicotyledonous weeds represented in the seed beds. Assigning to the commercial acid used a maximum strength, which may be assumed as having a specific gravity of 1.84 and purity of 95 per cent, and to the soil a minimum weight, which for this fine sand may be taken as 80 pounds per cubic foot, we find that even if all the acid applied were held in the upper 4 inches of soil the weight of H_2SO_4 used was only 534 parts per million of soil. That this treatment should have prevented all growth of weeds, in which both monocotyledons and dicotyledons were represented, while 600 parts did not even decrease the growth rate of wheat and vetch on the soil used by Lipman and Wilson, indicates a very considerable difference in behavior of acid in the two soils. As injury to pines is caused on the Morrisville soil by amounts of acid only one-third of that required to injure pines at Halsey, the contrast in the results between the Morrisville soil and that used by Lipman and Wilson is still more marked.

The observations made by the writer on the species of Equisetum, pines, grasses, and dicotyledons most common in the seed beds at

[1] Loew, Oscar. Studies on acid soils of Porto Rico. Porto Rico Agr. Exp. Sta. Bul. 13, p. 6, 1913.

[2] Cameron, F. K. Op. cit., p. 66.

[3] Lipman, C. B., and Wilson, F. H. Toxic inorganic salts and acids as affecting plant growth. *In* Bot. Gaz., v. 55, no. 6, p. 409–420, 1913.

Halsey indicated a considerable variation in resistance to sulphuric acid between species of these four phylogenetic groups, exceeding the variation between different species in the same group. It further appeared that, for the four main groups represented, the higher the group in the evolutionary scale the greater the susceptibility of its representatives to injury, not only by sulphuric acid but by hydrochloric and nitric acids and by some of the toxic salts. It is understood, of course, that these differences would not be expected to obtain with all species of these groups, and parallel water-culture tests with the species observed by the writer would probably show that some of the differences in susceptibility indicated in the nursery tests were due to other factors than variable protoplasmic resistance. The experiments reported in the foregoing were devised primarily for developing disease-control methods, and interpretation of many of the direct effects on the seedlings is of necessity difficult.

From the practical standpoint, it seems probable that sulphuric acid can not be used alone as a disinfectant for sandy soil soon to be sown with truck crops. This is at least true if the plants to be grown prove as susceptible to acid injury as the dicotyledonous weeds encountered in these experiments seemed to be. However, acid can probably be applied with safety on most soils several days before sowing if air-slaked lime sufficient to counteract three-fifths or more of the acid used is raked into the surface soil just before seed sowing. Sulphuric acid is so much cheaper than formalin that if subsequent lime neutralization is found practicable this acid may in many cases supplant both heat and formaldehyde as a soil disinfectant for work in which immediate reinfection with parasites is not feared. The writer's experience indicates that, aside from the destruction of parasites, soil treatment with acid followed by lime results in a considerable increase in the growth of many plants, in some cases being more prompt and marked than that following heat disinfection.

SUMMARY.

Sulphuric, hydrochloric, and nitric acids, and copper sulphate used in disinfection of seed-bed soil caused injury to the roots of pine seedlings and prevented the development of many species of angiospermous weeds. All cause injury to pines by killing the growing apex of the radicle immediately after the seed germinates. They can be used to disinfect pine seed beds only if the operator knows how to recognize and prevent such injury to the pines. Typical healthy and acid-injured seedlings are shown in Plate I, figures 1, 2, and 3, and a method by which injured seedlings can be distinguished from others is described on page 9. Many injured seedlings later resume root growth and recover (Pl. I, fig. 4, and text figs. 1 and 2). Injury is due to the concentration of the disinfectant in the surface soil

consequent on the capillary rise of the soil solution and the evaporation of water from the soil surface. It is found that in a sandy Nebraska soil all injury can be prevented by very frequent watering during the germinating period (pp. 11–12). It can also be prevented in the case of acid applications by adding lime to the soil shortly after treating with the disinfectant (pp. 21–22). The lime method, while undesirable in the case of pines, is probably the only one which will prevent injury to angiospermous seedlings. The acids can be applied to seed beds at the time of sowing without any injury to dormant pine seed. Formaldehyde and mercuric chlorid in sufficient disinfecting strengths must be used several days before seed sowing, as they are able to kill dormant pine seed in the soil. Formaldehyde applied at or before seed sowing never causes the injury to germinating pines that is caused by the acids and salts.

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THE EUROPEAN PINE-SHOOT MOTH; A SERIOUS MENACE TO PINE TIMBER IN AMERICA.

By August Busck,
Entomological Assistant, Forest Insect Investigations.

INTRODUCTION.

One of the most injurious insects to pine forests in Europe is a small orange-red moth, the larva of which eats out the new buds and kills or deforms the young twigs of pine trees, so as seriously and permanently to lower their timber value. This European pine-shoot moth, which is known under the scientific name *Evetria buoliana* Schiffermiller, has within very recent years been accidently introduced into America on imported European pine seedlings and has unfortunately become established in several widely separated localities in the eastern and middle western States.

Early last summer (1914), a correspondent of the Bureau of Entomology complained of a serious insect injury to European pines under his surveillance on Long Island, and sent examples of the injury and of the larvæ causing it; the latter could not be identified as those of any of our known American pine pests, and the writer was therefore authorized to visit the affected localities in order to ascertain the extent of the injury and to obtain sufficient live material for study and rearing. From this material a large number of moths emerged during the latter part of June and these were at once recognized as the famous European pine-shoot moth.

Subsequent surveys, undertaken by the bureau through Mr. Carl Heinrich and the writer, established the fact that the species has been repeatedly introduced on European nursery stock, and that it has become established in nurseries and parks in several localities scattered over nine States.

In view of the experience with other introduced European insects, and considering the very serious financial loss caused abroad annually by this insect, its introduction into this country gives just cause for alarm, because incalculable injury may result to the vast American forest interests if this insect is permitted to become generally established on our native pines.

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Some idea of the extent and permanent character of the injury which this insect is capable of inflicting may be gained from the illustration (Pl. I) of a European pine forest which has been infested by it for several years in succession, with the result that a majority of the tree trunks are so twisted and crooked that their value as timber is materially lessened.

HISTORY OF THE SPECIES IN EUROPE.

The species is a constant menace to pine forests in Europe and annually causes serious depredations, especially to young plantations of pine, in spite of continual preventive work against it. It has been the subject of much study and of an extensive literature from the time it was first described by Schiffermiller in 1776 to the present day. The species was named in honor of a Vienna entomologist, Baron Buol, who studied its injurious work during the latter part of the eighteenth century; since then numerous accounts have appeared of particularly severe outbreaks in many parts of Europe, from England to Russia, and from Scandinavia to southern France. It also occurs in Siberia.

One such outbreak in Denmark, in 1805–1807, is recorded by Niemann (1809).[1] This was so serious as nearly to cause pine culture to be abandoned in that country as hopeless. It is interesting to note that at that time the same preventive means were resorted to as are now employed against the insect, namely, the wholesale pruning and burning of all infested twigs.

The German forest entomologist, Ratzeburg, counted *Evetria buoliana* one of the most injurious forest insects and gave a detailed account (1840) of the life history, structure, and economic importance of the species. He mentioned especially an unusual outbreak in 1836–1838, which covered many parts of Europe. In the province of Furstenau the Rochesberg Mountain, which was covered with pines, became so seriously infested that it was under consideration by the authorities to burn it off and plant new trees. Other localities were only saved by strenuous systematic collecting of the infested twigs; thus, in the small province of Kesternich alone, 150,000 larvæ were gathered and destroyed.

Judeich and Nitsche (1895) state that the injury caused by *Evetria buoliana* is often fatal to the pine plantations. To quote from these authors, "If the attack is slight, it results in the branching of the tree, but if the attack is more severe and continued for several years, as we have seen it, then hardly any bud is spared and the pines become stunted into miserable small bushes from which numerous

[1] Dates in parentheses refer to "Literature," pp. 10–11.

branched shoots and large needle tufts stick out." These authors record many severe outbreaks and mention especially one in 1883–1885, in the Royal Forest Reserve, Pillnitz in Saxony, where nearly 75 acres of young pines planted in 1878 became infested to such an extent that hardly a shoot was spared, and in 1884 the entire plantation presented a pitiful, crippled appearance.

J. E. V. Boas (1898), who has made original investigations of the insect in Denmark, considers it one of the most injurious insects affecting forest trees. Among other outbreaks he mentions one in Jutland, Denmark, extending through several years around 1870, which "threatened the total destruction of the pine plantations."

The Belgian authority on forest insects, G. Severin (1901), regards *Evetria buoliana* as the most injurious insect to pines in Europe, and emphasizes the lasting injury to the timber resulting from even slight attacks of this insect.

All other European handbooks on entomology or on forestry contain similar accounts of this insect and express the same opinion as to its destructiveness to pine.

FOOD PLANTS.

Evetria buoliana is confined to pine and does not attack other coniferous trees, as spruce or larch, even though these grow alongside of the infested pines. While the species is most often mentioned on the yellow pine, or Scotch pine,[1] in Europe, because this is preeminently the forest tree of importance there, it attacks all species of Pinus indiscriminately, according to Ratzeburg and other authorities, and the American infestations have come in on European seedlings of the Austrian pine [2] and on mughus pine [3] quite as often as on Scotch pine.

According to Ratzeburg and Severin, it also attacks and is equally injurious to American white pine,[4] which is cultivated in Europe; and Mr. Carl Heinrich found the species on a small lot of another native American pine,[5] which was growing immediately surrounded by infested European pine seedlings.

These latter records are particularly significant, as they prove beyond question that the pest will spread to our native American pines if not prevented.

The species attacks mainly young trees between 6 and 15 years of age, but it is often excessively destructive to younger plantings and seedlings and injurious also to older trees, though trees of 30 years or older are rarely seriously affected.

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[1] *Pinus sylvestris.*
[2] *Pinus laricis* var. *austriaca.*
[3] *Pinus montana* var. *mughus.*
[4] *Pinus strobus.*
[5] *Pinus resinosa.*

INTRODUCTION AND DISTRIBUTION IN AMERICA.

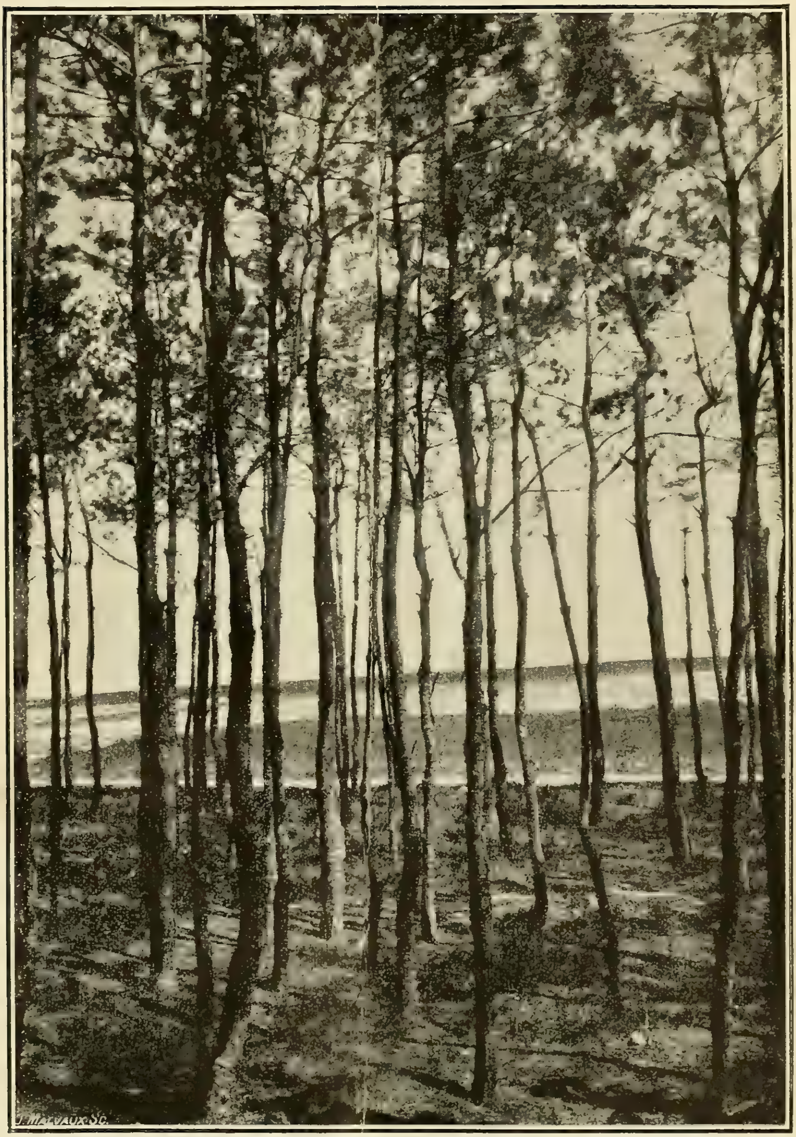
American nurseries have imported many thousands of pine seedlings annually from Europe, especially from France, Belgium, Holland, Germany, and England. Importations normally take place in the fall, winter, and early spring. At this time of the year the young larvæ of the pine moth lie dormant within the buds, so that an infestation is easily overlooked. It is evident that the pest has been present in a number of shipments of late years and that it thus has been introduced repeatedly into American nurseries. In a great majority of these cases, however, the species has been unable to establish itself and has died out during the first year. Many of the larvæ die from overheating en route, or from various other unfavorable circumstances incident to the handling and transplanting of the seedlings under different climatic conditions. Only by a combination of favorable conditions would the few surviving larvæ have been able to develop into moths and succeed in establishing the species in this country. This is probably the reason why the species as yet has become established in comparatively few American localities. It appears that such established infestation has taken place only in very recent years and especially within the last two years, or since the demand for European pines has become general.

Up to the present time the European pine moth has been discovered in only 32 nurseries and private estates, representing 20 localities in 9 States, namely:

State.	Locality.	Discovered in—
Illinois	Chicago	Private grounds.
Do	Glenview	One nursery.
Do	Dundee	Do.
Do	Western Springs	Do.
Do	Deerfield	Do.
Do	Kenilworth	Two private grounds.
Do	Bloomington	One nursery.
Ohio	Tippecanoe City	Do.
West Virginia	Elm Grove	Do.
Pennsylvania	Pittsburgh	Private grounds.
Do	Philadelphia	One nursery.
New Jersey	Somerville	One estate.
New York	Long Island	Nine nurseries and estates.
Do	Tarrytown	One nursery and one estate.
Do	Elmsport	One estate.
Massachusetts	Dedham	One nursery.
Do	North Abington	Do.
Do	Worcester	Do.
Connecticut	New Canaan	Do.
Rhode Island	Newport	Two nurseries and one estate.

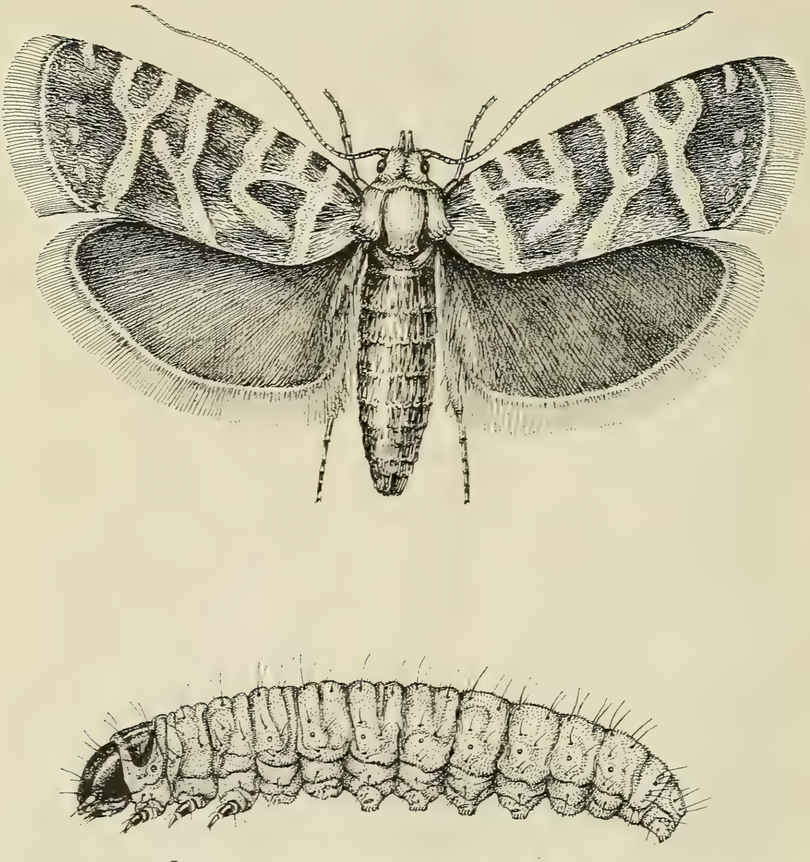
In none of these localities, except on Long Island, has the species existed for more than the last two years, and in most of them it has become established only within the last year.

But the survey for this insect has so far covered only about 60 localities, which could be reasonably suspected to harbor the pest because it was known that importations of European seedlings had



WORK OF THE EUROPEAN PINE-SHOOT MOTH (EVETRIA BUOLIANA).

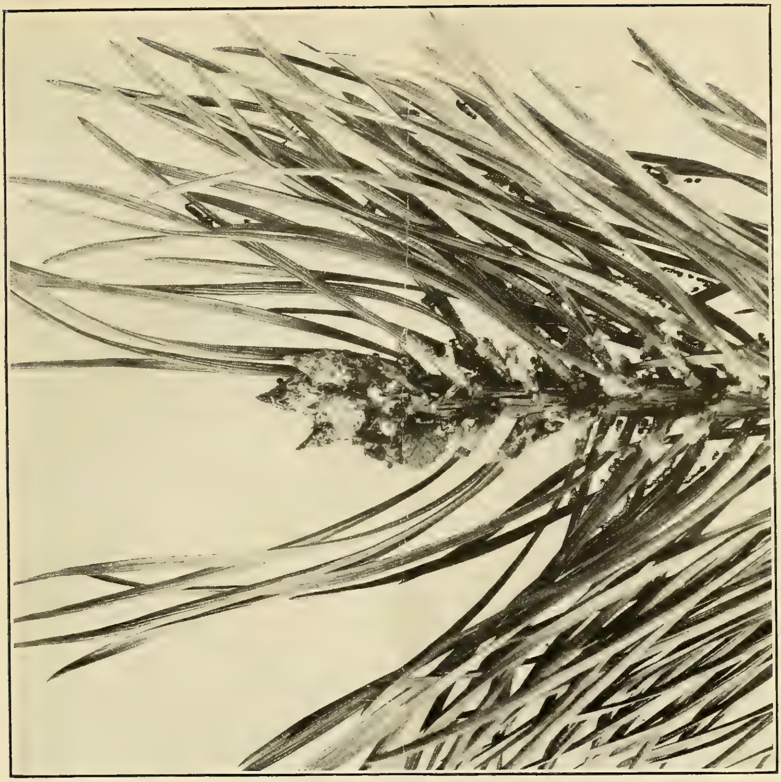
Section of European pine forest showing deformations in the trunk of *Pinus sylvestris* resulting from several consecutive years' injury. (After G. Severin.)

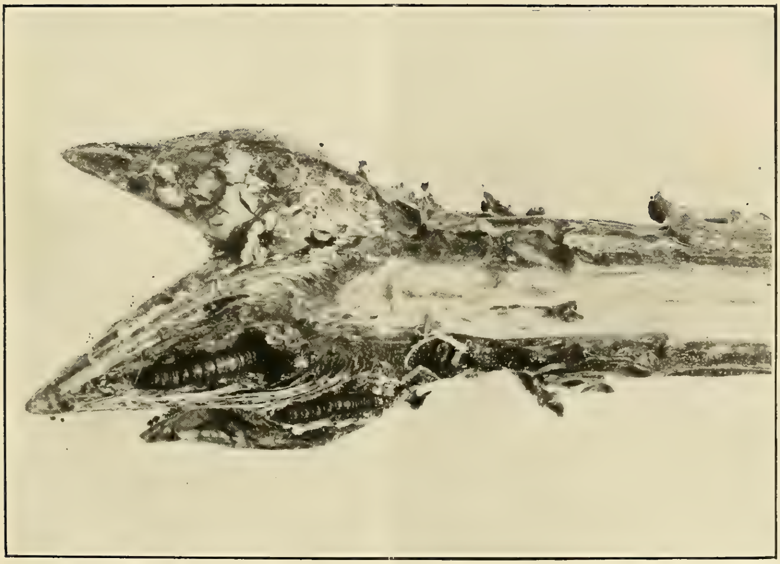


STAGES OF THE EUROPEAN PINE-SHOOT MOTH.

Moth and full-grown larva; both greatly enlarged. (Original.)

[Drawings by Miss Mary Carmody.]



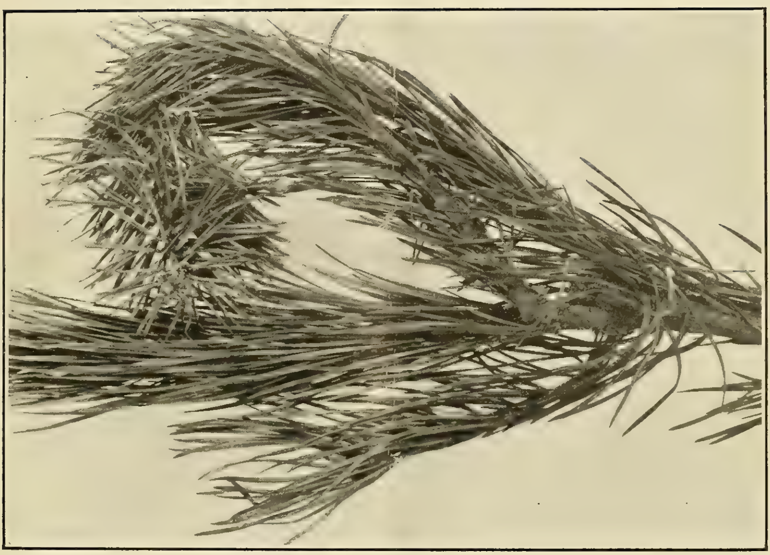


WORK OF THE EUROPEAN PINE-SHOOT MOTH.

Fall work of the young larvæ in the buds of *Pinus sylvestris*. (Original.)

WORK OF THE EUROPEAN PINE-SHOOT MOTH.

Malformations in pine resulting from injury by this pest. (Original.)



WORK OF THE EUROPEAN PINE-SHOOT MOTH.

Twisted growth of European pines caused by the work of this insect. (Original.)

WORK OF THE EUROPEAN PINE-SHOOT MOTH.

Typical first, second, and third years' growth of pine, after the primary injury by this insect, known as "baionnette" or "posthorn." (Original.)

[Photographs by Mr. H. C. Sands, of the New York Department of Agriculture.]

ken place, and the indications are very strong that the pest has be-
ne established in several other widely distributed localities, either
direct importation from Europe or by distribution from infested
nerican nurseries. This is particularly to be suspected of locali-
s where large importations and plantings of European pines have
en made.

As yet the pest has been found only in nurseries and private parks
pplied by these infested nurseries. In no case has it yet been
und on forest trees in America. The species is therefore at present
inly a nursery problem in this country and consequently may yet
controlled and possibly even eliminated by proper measures under
deral and State supervision. That this condition can not long
lure and that the pest, if not checked, will soon multiply and
read to native pines outside of nurseries and pass beyond the pos-
ility of elimination is clearly indicated by all the evidence on
nd.

LIFE HISTORY.

In Europe the moths (Pl. II, upper figure) issue in July, some-
nes as early as the end of June, and in the warm evenings they
arm around the pines in large numbers. During the day they sit
ietly on the branches, as can be ascertained by giving the tree a
arp jolt, which will cause the moths to fly out. When the insect sits
ll on the food plant it is not easily discovered, for the apparently
iking orange-red color blends well with the natural surroundings
d therefore must be classed as a protective coloration. Early in
igust the eggs are laid singly on the new buds for next year's
owth, the terminal cluster of buds being nearly always chosen for
iposition. The young larva soon hatches and eats its way into the
d, making itself a roomy cell by devouring the live inside part. It
ains a length of only a few millimeters during the fall months, and
erwinters within the hollow bud. At this stage its presence is
sily overlooked, though a trained eye will discover a small exuda-
n of pitch over the entrance hole differing from the normal exuda-
n of the buds. (See Pl. III.)

In May, as soon as the sap begins to rise in the trees, the larva
e buds. (See Pl. III.)
ves its winter quarters and bores into the bud next thereto, in
rn destroying this and as many others as it needs for food. As
e remaining buds adjoining begin to grow into young shoots the
rva attacks them. It eats the entire inside of the youngest shoots
d these consequently die. The more developed shoots are injured
ly on one side, and these sometimes continue to grow, but are bent
wnward at the injured spot. The larva (Pl. II, lower figure) feeds
ly on the soft growth on which the needles have not yet appeared,
d by the time the needles have developed all, or nearly all, of the
oots in the infested cluster have become dead or injured. The

larva then makes a silk-lined chamber within one of the hollow shoots and here it pupates. After about three weeks the spiny pupa pushes itself half way out through the dry wall of its chamber and the moth, or adult, issues.

The full life history of the species in America has not been ascertained, because a full year has not elapsed since it was first discovered here. While in the main it is the same as in Europe, a very distinct difference has already been noticed, due to the longer and warmer summer and fall in this country. In Europe the young larva attacks only one bud and attains very little growth before it enters the dormant winter season, but in the warmer climate of America the larva eats out two, three, or more buds and attains nearly half of its growth before winter. This, of course, tends to make the species even more injurious here than it is in Europe.

While it is altogether probable that the species has here only one generation annually, as in Europe, the possibility is not absolutely excluded that on account of the longer season it may eventually develop two generations annually like the allied native species. This, of course, would greatly increase its power for injury.

CHARACTER OF INJURY.

During the entire spring the infested twigs are very noticeable by reason of the dead and injured buds and young shoots, and the empty pupa skin sticking out of the destroyed shoot is also a familiar and easily noticed sight during the summer months; but the extent of the injury caused by this insect is only realized later in the season, when the new growth is found to be either quite destroyed or permanently injured.

As may be gathered from the foregoing account of the life history, each one of these insects does very considerable damage, not only by destroying a large number of buds and young shoots but by injuring the adjoining shoots which remain and which normally should supplant the destroyed leaders; thus the trees are permanently disfigured. These injured shoots bend downward and outward and afterwards grow upward again in a curve, in the attempt to continue the normal upward growth of the tree. This results in a characteristic malformation (Pls. IV, V, VI), so familiar in European pine forests that it has a popular name in each country—as "posthorn" and "waldhorn" in Germany and Holland and "baionnette" in France, while the few examples which have so far occurred in America have suggested the name "Dutch pipe" to those who have noticed it. This injury does straighten out somewhat during the successive years' growth, but never can be fully remedied and will always be noticeable and a serious detriment to the timber (Pl. I). Injury of this character is the result even when the species is present in only small numbers, the

repeated infestation of the leading twigs during several consecutive seasons producing additional malformations which result in a much distorted tree of little commercial value. If the pest becomes more abundant, then the trees are transformed by the effect of the injury into unsightly crippled bushes with no commercial value.

DESCRIPTION.

THE ADULT.

(Pl. II, upper figure.)

The European pine-shoot moth is a small, gayly colored moth, about one-half inch long and measuring about three-fourths of an inch across with the wings extended. The head and its appendages and the thorax are light orange-yellow, and the abdomen is dark gray. The forewings are bright ferruginous orange, suffused with dark red, especially toward the tips, and with several irregular, forked anastomizing, silvery crosslines and costal strigulæ; the hindwings are dark blackish brown. The legs are whitish, the anterior ones reddish in front.

THE EGG.

The egg is very small, flat, whitish in color, and is laid singly at the base of a bud. Dissection of a female abdomen proves that upwards of a hundred eggs are laid by each female; this is a rather greater fecundity than is normal in this group of insects.

THE LARVA.

(Pl. II, lower figure.)

The young larva is dark brown with deep black head and thoracic shield, the latter divided by a narrow central line. The body of the older larva becomes somewhat lighter, but is still much darker than the larva of any of our allied native species. The full-grown larva is two-thirds of an inch long.

THE PUPA.

The pupa is stout, robust, light chestnut brown with darker head and back. The wing covers reach to the end of the fourth abdominal segment. The abdominal segments are armed with rings of short, sharp, blackish-brown spines.

ALLIED AMERICAN SPECIES.

There are in this country several indigenous species closely allied to *Evetria buoliana*, and like it confined to pine. Some of these already constitute a serious problem and periodically do considerable

damage to pine forests and more often to pine nurseries. They are the more capable of injury because there are two generations annually and they thus have two chances each year to accomplish their damaging work. None of these native species can, however, even with this advantage, be compared in destructiveness to the European species just introduced. This is partly due to the larger size of the introduced species and to the greater voracity of the larva, but is mainly due to the difference in the attack, which causes a different reaction of the tree.

The larva of the native species of the genus confines itself to a single twig and finds its food within this or within a single bud, or at most a few buds. This bud or twig dies, but the tree responds with the natural growth of the next set of buds and very often recovers from the injury without permanent disfigurement. The resulting injury to the trees is serious only when these native species are present in unusually large numbers. Moreover, each of the native American species is more or less confined to a single or a few species of Pinus, but the European pine-moth thrives indiscriminately on all species of Pinus and has consequently a greater chance to become excessively abundant. While several of the native species are continually of some economic importance and periodically become a serious menace even to larger trees, it is mainly when they occur in large numbers in nurseries that they become really troublesome. Large trees become checked in their growth by the loss of terminal twigs, but are not necessarily seriously deformed in their future growth, although an undesirable forking of the tree top is a quite common result.

On the other hand, the larva of the European pine-shoot moth is very voracious and not only destroys a number of buds and young sprouting shoots by eating their interior, but it invariably damages the remaining shoots in the cluster by nibbling their bases on the inner side. The subsequent growth of these injured shoots, in the effort to supplant the destroyed leader, causes greater permanent injury to the value of the tree than if they were entirely removed.

NATURAL ENEMIES.

Evetria buoliana in Europe is, to some extent, kept in check by a large number of parasitic enemies. As early as 1838 Hartig[1] recorded 14 ichneumonid wasps and 1 tachinid fly[2] which he had reared from pupæ of the pine-shoot moth. It has since been ascertained that there are several other parasites; among the ichneumonids Ratzeburg considered the following three, which he himself had reared, as the more important: *Pristomerus vulnerator* Panz., *Cremastus interruptor* Grav., and *Orgilus obscurator* Hald.

[1] See "Literature," p. 10.

[2] *Actia pinipennis* Fallen.

To promote the good work of these parasites specially constructed rearing houses have been erected in Europe during bad outbreaks of the pine moth. The infested twigs are collected in these small houses, which permit the escape of the parasites but not of the moths.

It is reasonable to suppose that some of the native parasites on some of the native species of Evetria will in time also attack *Evetria buoliana* in this country—in fact, parasitized larvæ have already been observed—but these native parasites can not be relied upon to keep in check their natural hosts, the American pine moths, which sporadically become very abundant and injurious in spite of the parasites, and presumably will be less effective in controlling the newly introduced host.

METHOD OF CONTROL.

The larva of the European pine-moth is so effectively protected within the buds that it can not be reached by any insecticide, and the only method of combating it is that used in Europe for more than a hundred years, namely, the pruning and destruction of the infested buds and twigs together with the larvæ they contain. Such hand picking is practiced every year in the government-controlled forest reserves of Europe.

This pruning must be done while the insect is within the twigs, and while it may be done throughout the entire year, except during the midsummer months when the insect is in the adult stage, it can be most profitably done in the fall and winter months while the young larvæ are yet within the undeveloped buds, because the pruning at this time will enable the secondary set of buds to develop in the spring without delay. The only drawback to the collecting of the larvæ in the fall and winter is that the infested buds are then less noticeable than in the spring when the injury is further developed. A little practice, however, soon enables instant recognition of the infested buds, even by an unskilled laborer; the slight exudation of pitch at the base of the bud covering the entrance hole of the larva (Pl. III) is very characteristic and easily recognized when once known.

In the spring, when the buds develop into young shoots, the injury is very much more apparent, and anybody can then distinguish the infested twigs at a glance. For this reason it is advisable to have the trees gone over again in the spring, so as to remove any infestation which has been overlooked in the fall. In America the work of the larva in the fall (September, October, and November) has progressed far more and is much more easily discovered than is the case in Europe, where the larvæ have attained very small proportions and

have attacked only one or two buds before the winter resting period intervenes.

The fact that this species is stationary during the greater part of the year and only found within definite parts of certain kinds of trees, namely, in the next year's buds of pines, makes effective control work much easier than is the case with insect pests which are general feeders and which are not confined to definite parts of the food plant, as, for example, the gipsy moth or the browntail moth. While the European pine-shoot moth is confined to nurseries and private parks and has not spread to the native pines, it should prove a comparatively easy task to eradicate the species absolutely within any limited area. At the present time it would even seem possible completely to stamp out this dangerous pest in America, and forestall the infestation of our native pine forests, provided that the danger of new infestation is removed. But when once the species has multiplied sufficiently to become generally distributed on the native pines the possibility of eradication will be past.

SYNONYMY OF EVETRIA BUOLIANA SCHIFFERMILLER.

Tortrix buoliana Schiffermiller, Syst. Verz. d. Schmett., p. 128, 1776.

Coccyx buoliana Treitschke, Schmetterlinge von Europa, vol. 8, p. 140, 1830.

Tortrix (Coccyx) buoliana Ratzeburg, Die Forst-Insecten, vol. 2, p. 202, 1840.

Retinia buoliana Guénée, Europaeorum Microlepidopterorum index methodicus, p. 46, 1845.

Coccyx buoliana Herrich-Schäffer. Bearb. d. Schmetterlinge von Europa, vol. 4, p. 221, 1849.

Evetria buoliana Meyrick, Handbook of British Lepidoptera, p. 470, 1895.

Evetria buoliana Rebel, Catalog der Lepidopteren des palaearctischen Faunengebietes, T. II, No. 1851, 1901.

LITERATURE.[1]

1776. Schiffermiller, I. Systematisches Verzeichniss der Schmetterlinge der Wiener Gegend. Wien.

Original description of *Evetria buoliana.*

1809. Niemann, E. Forststastistik der Danischen Staaten, Altona.

Describes outbreak in Denmark in 1805–1807, and the collecting of larvæ in the effort to control the species.

1838. Hartig, T. *Tortrix buoliana. In* Jahresberichte über die Fortschritte der Forstwissenschaft und forstlichen Naturkunde, Jahrg. 1, Heft 2, p. 267–268, Berlin.

Records the rearing of 15 species of parasites from *Evetria buoliana.*

1840. Ratzeburg, J. T. C. Die Forst-Insecten, T. 2, p. 202–207, Taf. XIV, fig. 4. Berlin.

Detailed account with illustrations of the life history, work, economic importance, remedies, natural enemies, and literature of the species, with notes of severe outbreaks in Germany, 1835–1838.

[1] This is not intended to be a complete bibliography of *Evetria buoliana;* a large number of special articles have appeared in various publications in Europe, and every handbook on insects or forestry contains more or less exhaustive accounts of this pest.

1895. Judeich, J. F., and Nitsche, H. Lehrbuch der mitteleuropaischen Forstinsektenkunde, Bd. 2, p. 1004–1008. Wien.

Condensed (5 pages), life-history and economic importance with original figure of the injury done by the species.

1897. Lovink, H. J., and Ritzema Bos, J. Schade in jonge dennen bosschen teweeg gebracht door rupsen uit het bladrollergeslacht *Retinia* Gn. ("dennenknoprups" "dennenlotrups" "harsbuilrups"). *In* Tijdschr. Plantenziekten, Jahrg. 3, Afl. 4, p. 83–133, figs. 6, pls. V–VII, Oct.

Detailed account of the species and its injury, with colored plates.

1897. Severin, G. Insectes. Extrait du Catalogue détaillé et illustré du Pavillon des eaux et forêts à l'Exposition internationale de Bruxelles-Tervueren, p. 46–49, pl. X. Bruxelles.

Contains short illustrated account of *Tortrix* (*Retinia*) *buoliana* Schiffermiller and its injury: Plate I of the present paper has been copied from this article.

1898. Boas, J. E. V. Dansk Forstzoologi. Copenhagen.

Condensed life history, injury, and references, with original observations and figures.

1898. Hess, R. A. Der Forstschutz, ed. 3 enl., v. 1, p. 492–494, figs. 174–175. Leipzig.

Condensed handbook information on *Tortrix* (*Retinia*) *buoliana* Schiff.

1901. Severin, G. Le genre *Retinia*, Pyrale des pommes, des bourgeons, de la résine. *In* Bul. Soc. Cent. Forest. Belg., t. 8, p. 598–605, 674–685, 2 pls., 7 figs.

Monographic account of the three most important injurious species of the genus *Evetria* in Europe, with text figure and colored plate of *Evetria buoliana*. It should be noted that the larva figured under and credited to *Evetria buoliana* belongs to *Evetria resinella*, figured on the next colored plate, and vice versa.

1912. Gillanders, A. D. Forest Entomology, ed. 2. Edinburgh and London.

Condensed handbook information.

1913. Nüsslin, O. Leitfaden der Forstinsektenkunde, 2. neubearb. und verm. Aufl., p. 417–418, figs. 350, 352. Berlin.

Condensed handbook information on *Grapholitha* (*Evetria*) *buoliana* Schiff.

1914. Busck, August. A destructive pine-moth introduced from Europe (*Evetria buoliana* Schiffermiller). *In* Jour. Econ. Ent., v. 7, no. 4, p. 340–341, pl. IX, August.

First notice of the pest in America.

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BULLETIN OF THE
U.S. DEPARTMENT OF AGRICULTURE
No. 171

Contribution from the Bureau of Biological Survey, Henry W. Henshaw, Chief.
February 5, 1915.

(PROFESSIONAL PAPER.)

FOOD OF THE ROBINS AND BLUEBIRDS OF THE UNITED STATES.

By F. E. L. Beal, *Assistant Biologist.*

INTRODUCTION.

Few native American birds are more universally cherished than those well-known harbingers of spring, the robins and bluebirds. On esthetic grounds alone they receive full protection, partly from the romance that clusters about them in story and legend and partly because of their graceful shape and movement, bright color and pleasing song, and close association with man and his works. Quick to realize their safety the birds nest and rear their young about human abodes, and at times becomes very abundant, their numbers frequently reaching such proportions that apprehension is felt that they may become dangerous to agriculture and horticulture. A study of their economic status therefore is of the utmost importance, especially when it is considered that a bird's reputation is very often affected one way or the other merely by hearsay evidence.

Investigation discloses that in addition to their pleasing qualities robins and bluebirds perform a very useful function in reducing the hordes of insect life constantly preying upon the crops of the farmer. In this work a large part of their food consists of insects and they feed their young upon them almost exclusively. It is recognized that birds are one of the necessary checks provided by nature upon the increase of the vast number of insects produced each year; that without them there would be a greater destruction of vegetation; and that certain crops of the farmer now regularly matured would, if raised at all, be raised only with increased difficulty and added labor. Prominent among the insect eaters are the thrushes, the group which includes the robins and bluebirds.

In the thrush family of North America are 11 species, but passing by the less familiar members, the thrushes proper (*Myadestes* and

Note.—This bulletin discusses the value of robins and bluebirds as insect destroyers and shows how the small damage done by the former may be reduced by supplying wild fruits to meet their requirements. It is for general distribution.

Hylocichla), there will be discussed in the present paper the food habits of members of the five species of American robins and bluebirds—the common robin (*Planesticus migratorius*), the varied thrush, or Oregon robin (*Ixoreus nœvius*), the eastern bluebird (*Sialia sialis*), the western bluebird (*Sialia mexicana*), and the mountain bluebird (*Sialia currucoides*). While the ranges of these birds in their subspecies extend entirely across the continent, the best known are the common robin and the eastern bluebird. Time and the further advance of cultivation into wilder areas may bring the other species into greater prominence.

The American robin (*Planesticus migratorius* and subspecies) is one of the most familiar birds of the whole United States; and in the extreme northwest there is found also the varied thrush, or, as it is locally known, the Oregon robin (*Ixoreus nœvius* and subspecies).

The eastern bluebird (*Sialia sialis* and subspecies) occupies the whole of eastern United States west to the base of the Rocky Mountains, and occurs also in southern Arizona; it is replaced beyond the mountains by two western species (*Sialia mexicana* subspecies and *Sialia currucoides*), which have much the same appearance and habits.

As robins and bluebirds are usually abundant wherever found the matter of their food supply deserves careful consideration, for wherever nature's lavish provision fails these birds must seek their subsistence either from cultivated crops or from the wild varieties especially left or provided for them by their human friends. A determination of the nature of their food therefore becomes of considerable economic importance. In the following pages is discussed in detail the economic status of the five species of these groups of birds.

ROBIN.

(*Planesticus migratorius* and subspecies.)

The common robin is probably the most familiarly known bird in the United States and has embellished the literature of its rural life to a greater extent than all other birds together. Having been made the object of a transferred affection it has received the love and protection which the ancestors of the American people formerly lavished upon the robin redbreast of Europe. The subspecies *Planesticus migratorius migratorius* is found throughout the United States east of the Great Plains and north of the Gulf States; and elsewhere are two closely related subspecies, one of which, *Planesticus migratorius propinquus*, is well known in the valley regions of the Pacific coast in winter and throughout the higher mountains in this section in summer; and the other, *Planesticus migratorius achrusterus*, is found in the higher regions of southeastern United States. The range of the species extends northward into Canada and even into Alaska.

While for the most part migratory in the northern half of the country, individuals remain all winter in many localities where shelter and food are assured. In eastern Massachusetts and at some places farther west there are cedar swamps which offer an abundant supply of wild fruit, and robins remain there throughout the winter in considerable numbers. Most of the species spend the winter from latitude 40° southward, and begin to move northward as soon as snow disappears. They arrive in New England in the latter part of March or early in April and in the northern States of the Mississippi Valley somewhat earlier. It is difficult to say just when the fall migration begins, as the first birds to leave are replaced by others from farther north. They are often very abundant in the latitude of Massachusetts during the first half of November, but by

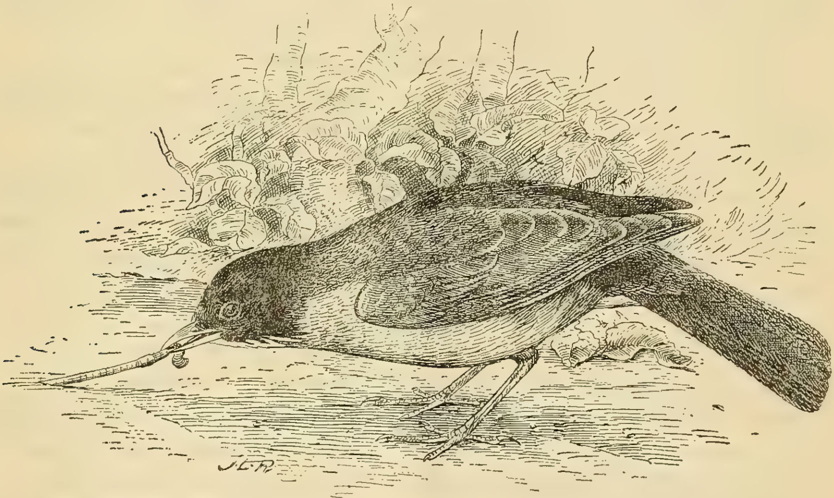

FIG. 1.—Robin (*Planesticus migratorius*).

the last of the month all have either left for the south or retired into winter quarters.

In its breeding habits the robin is very domestic, having learned to place a good deal of confidence in its human neighbors. It commonly selects orchards as nesting places, or fearlessly builds upon a projecting shelf of a piazza or under an open shed where persons pass many times during the day. Stone walls and stump fences are often utilized, and in one case known to the writer the nest was placed directly upon the ground. The bird's confidence is rarely abused and it is allowed to rear its brood undisturbed wherever the nest may be. Four young are commonly raised in a brood and two or more broods are reared in a season. In the northern part of the country, especially in New England, the bird is thought so well of that one is rarely killed or disturbed.

Owing to the complete protection the species enjoys, it sometimes becomes overabundant for the best interests of horticulture, and its depredations upon small fruits are so extensive as to try the patience of its whilom protectors and friends, the fruit growers. In spite of this the law still extends its protecting arm over the bird in most parts of the country, and fruit growers have to guard their crops as best they can. Many who grow fruit for home consumption declare that the robins take more than half the crop, and some have testified that they often take the whole.

Robert B. Roosevelt, writing from Sayville, Long Island, N. Y., says:

We have seven or eight cherry trees * * * in fair bearing of the finest sort. We never get a cherry! I mean this exactly. The robins eat or ruin the whole just before they get ripe enough for the human taste. They also take grapes and strawberries, but not on so wholesale a plan.

W. G. Castellow, of Waterloo, Me., writes:

When strawberries are cultivated in small patches of two or three rods in extent, the robins will take them all unless the berries are picked when hard, or the birds scared away by dogs, children, etc.

These are fair examples of much testimony received by the Department of Agriculture. There is no doubt that the bird often commits extensive ravages among small fruits, but there is reason to believe that the damage is limited to certain localities and is not general.

In the following details of stomach examination it will be noticed that a large percentage of the robin's vegetable food consists of wild fruit. This does not seem to have been true in the case of birds examined by earlier investigators. If, however, as appears from the present investigation, the robin prefers wild fruits to cultivated varieties, we have at once a probable explanation of the fact that some parts of the country enjoy almost complete exemption from the ravages of which others complain.

For a number of years the writer was engaged in the cultivation of small fruits in Massachusetts, and although robins were abundant about the farm they did no appreciable damage. On the farm where the writer lived when a boy was a fine collection of the choicest varieties of cherries. The fruit first to ripen each year was shared about equally by the birds and the family, but that which matured afterwards did not attract the birds, probably because in that section the woods and swamps abound with many species of wild fruits.

Reports of depredations upon fruit by birds come principally from the prairie region of the West. This is just what might be expected, for but few prairie shrubs produce the wild berries that the birds prefer and for lack of these the birds naturallly feed upon the cultivated varieties available. Reports of fruit losses caused

by birds in the East are usually from the immediate vicinity of villages or towns where there is no natural fruit-bearing shrubbery. From this it follows that an effective remedy for the ravages of birds upon cultivated fruits is to plant the preferred wild varieties. In the list given farther on (p. 13) are a number of species that are ornamental and usually are easily obtained.

On the western coast the habits of the robin appear to be the reverse of those of its eastern relative, for in summer it migrates northward or up into the high mountainous regions where it breeds, and in fall it returns to spend the winter in the valleys about orchards, vineyards, and cattle corrals; so that while in the East the robin is a summer bird, in the far West it belongs to the winter fauna.

Food.—The robin is omnivorous and feeds upon pretty much every eatable accessible. In spring when insect and other animal life begins to stir, this bird is on hand to take the first angleworms, snails, or sow bugs that show themselves. Then when the weather is a little warmer he takes the first beetles that appear, and so establishes a reputation for destroying useful Coleoptera (Carabidæ). At this time he eats the waste fruit left on the tree over winter, but when the early service berries (*Amelanchier*) ripen in June he feeds upon them, and later as the early cherries begin to color he tries them for variety. In July raspberries tempt his appetite and in August he fills up on grasshoppers. Thus each month brings something to supply his wants.

In investigating the food of the robin 1,236 stomachs from 42 States, the District of Columbia, and 3 Canadian Provinces were examined. They represent every month in the year and include the three subspecies generally recognized—*migratorius*, *propinquus*, and *achrusterus*. Analysis showed that the food consisted of 42.40 per cent animal matter and 57.60 per cent vegetable.

Animal food.—As the robin is an early migrant from the south he naturally preys on the first insects that come out from winter quarters. Useful Carabidæ, or predaceous ground beetles, which are among the earliest insects to appear in spring, form a very important element of the food of the first spring migrants among the birds. These beetles form 12.78 per cent of the food of the robin in April, and 8.57 per cent in March. After April, when other prey becomes more abundant, fewer appear in the food, but they are taken to some extent in every month and aggregate 5 per cent for the year. Beetles of the May-beetle family (Scarabæidæ) are eaten to the extent of 5.48 per cent of the yearly food, but in May, the month of their greatest abundance, they amount to 32.29 per cent, or nearly one-third of the diet. Various species of these beetles were found in 274 stomachs. Of these, *Lachnosterna*, the progenitors of the white grubs

that eat the roots of grass and other plants, were found in 64. Several other species of the family nearly as harmful were identified. The Colorado potato beetle was found in 2 stomachs, and both the striped and spotted squash beetles were identified in others.

Larvæ of the Lampyridæ or fireflies, which live in the ground and so fall an easy prey to the robin, were found in several stomachs to the extent of upward of a hundred in each. Several species of weevils or snout beetles, including the two clover weevils (*Phytonomus punctatus* and *Epicærus imbricatus*), the corn weevil (*Sphenophorus zeæ*), and a number of others, were identified. In June, 1911, 10 stomachs of robins were collected in Utah in the region infested by the newly imported alfalfa weevil (*Phytonomus posticus*) and 6 were found to contain these weevils in varying quantities. In all, the birds had taken 17 adults and 195 larvæ, which amounted to an average of 35 per cent of the food of each. This shows how readily birds avail themselves of a new kind of food. Beetles collectively amount to 16.72 per cent, of which Carabidæ make up 5 per cent and Scarabæidæ 5.48 per cent. Weevils or snout beetles amount to 2.13 per cent, and all others 4.11 per cent.

The robin evidently is not a lover of Hymenoptera (bees, wasps, etc.) as the total consumption is only 2.60 per cent. Of these, 1.57 per cent are ants and the remainder, 1.03 per cent, wild bees and wasps, except a few bits of a single worker honey bee (*Apis mellifera*). This is in strong contrast to the food of birds of the genus *Hylocichla*, which consists on the average of over 12 per cent of ants. It is evident that the robin does not care for ants; and as it is not adept at capturing active creatures it is not surprising that it does not eat many wasps or bees.

Hemiptera (bugs) constitute only 2.20 per cent of the robin's food, but are taken to some extent in every month. February and April are the months of greatest consumption, with something over 5 per cent in each; March and May stand next with more than 3 per cent. While eight families were identified, the Pentatomidæ (stinkbugs) greatly predominate. Probably the most interesting member of this order eaten by the robin is the chinch bug (*Blissus leucopterus*). This injurious insect was found in two stomachs, and its presence was suspected in several more.

Diptera (flies) are represented in the food of the robin almost entirely by larvæ of the March flies (Bibionidæ). *Bibio albipennis*, the species most often eaten by robins, breeds in colonies in the ground, feeding on grass roots. Naturally they are not found by the birds so often as if they were more generally distributed, but when found the whole colony is eaten. While several stomachs contained less than 100 each of these larvæ, at least 12 contained from 100 to 200; one contained 270, and another the remarkable number of 1,040.

In this last case the bird probably had the good fortune to find several colonies. March flies are not considered very harmful insects, but are prolific breeders, and that they do not do more damage is probably because they are so persistently preyed upon by robins. In February and March the number of these larvæ eaten is about 10 per cent of the bird's diet. In other months it is considerably less. The average for the year is 3.14 per cent. A few crane flies (Tipulidæ) and a few bits of other Diptera were taken by robins, but they do not constitute an appreciable percentage of the food.

Lepidoptera (mostly caterpillars) form a regular and fairly abundant constituent of the robin's diet. The maximum consumption occurs in May, when this item amounts to 23.96 per cent of the food. After this it gradually decreases to a little more than 1 per cent in November, when it again rises toward its maximum. Owing to the soft nature of these insects, very few can be identified. The army worm (*Heliophila unipuncta*) was recognized in six stomachs, but was probably represented in many more; the codling moth caterpillar (*Carpocapsa pomonella*) was found in two stomachs; a cabbage worm (*Pontia protodice*) in one; and the yellow-necked apple-tree worm (*Datana ministra*) in three. Undoubtedly many more destructive species were contained in the food, though unrecognizable, but as practically all caterpillars are harmful, any destruction of them may be set down to the credit of the bird. The total consumption amounts to 9.04 per cent of the food.

Orthoptera (grasshoppers and crickets) as a general rule are acceptable food for insectivorous birds, and when abundant are eaten by almost every species. The robin, however, does not display any special fondness for them except during the short time when they are most abundant. The west-coast robin evidently relishes these creatures even less than does his eastern relative, but this perhaps is partly accounted for by the fact that but few stomachs of the western robin can be taken in the summer, as the bird spends that season either in the far north or in high mountain regions. It is remarkable, however, that as a general rule western birds do not eat grasshoppers with the gusto shown by the corresponding eastern species. The robin consumes the greatest quantity of grasshoppers from June to September, when 73 per cent of the total number taken during the year are eaten, or somewhat more than 10 per cent of the whole food. In August, as would be expected, the consumption is greatest and amounts to 17.33 per cent. In the same months the meadowlark eats grasshoppers to the extent of 67 per cent of his monthly diet. The average annual consumption by the robin is only 4.76 per cent, while with the meadowlark it is 28.30. It is evident that during most of the year these insects are eaten by the robin only when nothing better is at hand. *Melanoplus devastator*, a near relative of the

Rocky Mountain locust, was identified in one stomach and was probably represented in many more.

Miscellaneous insects of various orders, none of special interest, make up 0.37 per cent of the food. Spiders were eaten to the extent of only 0.83 per cent and Myriapods (thousand legs), 1.21 per cent. Various other animals such as sow bugs, snails, and angleworms were taken occasionally and make up the remainder of the animal food, 1.53 per cent.

Following is a list of the insects and other items of animal food with the number of stomachs in which found:

HYMENOPTERA.

Pimpla marginata	1
Camponotus pennsylvanicus	1
Apis mellifera	1

COLEOPTERA.

Cicindela hirticollis	1
Cicindela punctulata	1
Cychrus lecontei	1
Cychrus obliquus	1
Elaphrus riparius	1
Elaphrus sp	2
Pasimachus sp	1
Scarites subterraneus	1
Dyschirius basalis	1
Dyschirius sp	1
Clivina punctulata	1
Clivina bipustulata	2
Podabrus aterrimus	1
Pterostichus morio	1
Evarthrus sodalis	1
Evarthrus sp	1
Amara impuncticollis	2
Amara interstitialis	6
Amara sp	8
Calathus gregarius	1
Platynus brunneomarginatus	1
Platynus limbatus	1
Platynus æneolus	1
Galerita sp	1
Lebia sp	1
Chlænius sp	2
Geopinus incrassatus	1
Cratacanthus dubius	2
Agonoderus lineola	1
Agonoderus pallipes	10
Agonoderus sp	1
Harpalus herbivagus	1
Harpalus pleuriticus	1

COLEOPTERA—Continued.

Harpalus sp	5
Selenophorus pedicularis	1
Stenolophus conjunctus	2
Stenolophus ochropezus	1
Stenolophus dissimilis	2
Anisodactylus discoideus	1
Anisodactylus carbonarius	1
Cnemidotus callosus	1
Bidessus affinis	1
Helophorus sp	1
Hydrocharis obtusatus	1
Cymbiodyta fimbriata	1
Sphæridium scarabæoides	1
Silpha lapponica	2
Silpha ramosa	2
Silpha sp	2
Staphylinus vulpinus	1
Philonthus hepaticus	1
Philonthus fusiformis	1
Philonthus occidentalis	1
Leptacinus grandiceps	1
Stenus sp	1
Orthopterus scutellaris	1
Hippodamia convergens	1
Hippodamia sp	1
Coccinella 9-notata	1
Chilocorus bivulnerus	1
Languria mozardi	1
Tritoma angulata	1
Hister sellatus	2
Hister harrisi	1
Hister immunis	3
Hister abbreviatus	2
Hister militaris	1
Hister curtatus	1
Hister 16-striatus	5
Hister americanus	14
Hister 17-striatus	1
Hister sp	1

COLEOPTERA—Continued.

Ips fasciatus	5
Cytilus sericeus	2
Byrrhus murinus	1
Lacon rectangularis	1
Monocrepidius vespertinus	2
Monocrepidius auritus	4
Monocrepidius bellus	3
Drasterius livens	1
Drasterius elegans	3
Drasterius sp	1
Dolopius lateralis	2
Melanotus cribricollis	3
Limonius subauratus	1
Corymbites cylindricollis	3
Telephorus bilineatus	2
Telephorus sp	2
Canthon simplex	1
Canthon sp	1
Copris minuta	1
Onthophagus hecate	9
Onthophagus sp	30
Ægialia opifex	1
Rhyssemus scaber	1
Rhyssemus sonatus	1
Atænius cognatus	13
Atænius imbricatus	1
Atænius sp	9
Aphodius fossor	2
Aphodius fimetarius	36
Aphodius ruricola	3
Aphodius serval	2
Aphodius inquinatus	45
Aphodius pardalis	2
Aphodius anthracinus	1
Aphodius robustus	1
Aphodius alternatus	3
Aphodius sp	27
Bolboceras farctus	1
Odontæus filicornis	1
Geotrupes blackburnii	2
Geotrupes sp	3
Macrodactylus subspinosus	1
Lachnosterna tristis	1
Lachnosterna sp	63
Anomala flavipennis	1
Anomala binotata	5
Anomala oblivia	1
Euphoria inda	4
Euphoria sp	1
Strangalia luteicornis	1
Chlamys plicata	4

COLEOPTERA—Continued.

Pachybrachys hepatica	1
Myochrous denticollis	6
Typophorus canellus	1
Graphops nebulosus	1
Colaspis brunnea	12
Leptinotarsa 10-lineata	2
Calligrapha similis	1
Plagiodera viridis	1
Galerucella americana	2
Diabrotica 12-punctata	1
Diabrotica vittata	1
Cerotoma trifurcata	2
Œdionychis interjectionis	1
Disonycha crenicollis	2
Disonycha sp	1
Odontota dorsalis	1
Haltica fuscoænea	1
Haltica tombacina	2
Systena elongata	2
Chætochnema denticulata	1
Cassida bivittata	1
Epitragus canaliculatus	1
Eleodes sp	3
Opatrinus sp	1
Blapstinus abbreviatus	1
Blapstinus pratensis	1
Blapstinus sp	1
Notoxus denudatus	1
Notoxus hepaticus	1
Notoxus sp	11
Thecesternus humeralis	1
Thecesternus sp	1
Epicærus imbricatus	1
Graphorhinus vadosus	1
Amnesia sordida	1
Amnesia sp	1
Phyxelis rigidus	1
Mylacus soccatus	2
Geoderces melanothrix	1
Cercopeus chrysorrhœus	1
Otiorhynchus ovatus	4
Tanymecus confertus	2
Aphrastus tæniatus	2
Sitones lineellus	3
Sitones californicus	1
Sitones flavescens	7
Sitones hispidulus	4
Sitones binellus	1
Sitones sp	5
Phytonomus punctatus	4
Phytonomus nigrirostris	1

COLEOPTERA—Continued.

Phytonomus posticus	6
Macrops sp	8
Cleonus 4-lineatus	1
Cleonus sp	1
Onychylus nigrirostris	1
Onychylis sp	1
Conotrachelus anaglypticus	2
Conotrachelus sp	1
Acalles clavatus	1
Tyloderma æreum	1
Tyloderma nigrum	1
Tyloderma baridium	1
Tyloderma angustatum	1
Rhinoncus pyrrhopus	2
Baris ærea	1
Centrinus picumnus	1
Balaninus sp	2
Sphenophorus parvulus	11
Sphenophorus zeæ	3
Sphenophorus sp	3

DIPTERA.

Bibio albipennis	24

LEPIDOPTERA.

Pontia protodice	1
Hadena sp	1
Mamestra subjuncta	1
Heliophila unipuncta	6
Catocala sp	1
Arachnis zuni	1
Schizura concinna	1
Datana ministra	3
Carpocapsa pomonella	2

NEUROPTERA.

Corydalis sp	1

HEMIPTERA.

Tibicen septendecim	2
Drœculacephala reticulata	1
Xerophlœa viridis	1
Nezara hilaris	1
Nezara sp	1
Proxys punctulatus	1
Blissus leucopterus	2
Myodocha serripes	4
Euthoctha galeator	1
Leptoglossus oppositus	2
Metapodius femoratus	3
Corizus nigristernum	1

ORTHOPTERA.

Tettigidea lateralis var. *polymorpha*	1
Melanoplus devastator	1
Conocephalus sp	1

ARACHNIDA.

Phidippus audax	1

MOLLUSCA.

Helix mobileana	1
Orohelix strigosa	1
Succinea luteola	1
Succinea sp	1
Pupoides fallax	1
Lymnœa sp	1
Melampus bidentata	1

Vegetable food.—Over 50 per cent of the robin's food consists of fruit and more than four-fifths of this are wild species, even if strawberries, raspberries, and blackberries are classified as cultivated, which is not always the case. Many complaints have been made against this bird on the score of fruit eating and in many cases they are well founded. In the vicinity of towns where cultivation and improvements have swept away the wild fruits, or when for any reason the crops of wild fruit fail, the birds are forced to resort to cultivated varieties, and disaster to the farmer results.

While such cases are not numerous or of very great importance in the East, it is quite otherwise in California, where the robin is a winter bird and is abundant at just the time when wild fruits are largely out of bearing, except such as retain their fruit over winter.

In years when this customary food is scarce, robins appear in the valleys in immense numbers and eat olives so eagerly and persist-

ently that the loss is often serious and occasionally disastrous. Sometimes, indeed, it is only by the most untiring efforts with considerable outlay of labor and money that any part of the crop can be saved. Fortunately, such extensive damage is not done every year, although here and there the olive crop may suffer.

There is probably no more striking example of this exceptional and intermittent damage to fruit by birds than that which occurred in the winter of 1900–1901. In that year olive orchards in various parts of California were invaded by immense numbers of robins, which ate the fruit and in some instances destroyed the whole crop. Even in orchards where persistent effort was made to kill them or drive them away they ruined from one-fourth to one-half of the yield. Olive orchards in Santa Clara Valley were especially afflicted. Paul Masson, who owned two orchards near Saratoga, as quoted by the San Jose Mercury of January 17, 1901, says:

In my largest orchard of about 500 trees adjoining a larger orchard of about 50 acres on the El Quito farm, which is owned by E. E. Goodrich, are thousands of robins, which are destroying all the fruit on the trees. About two months ago I estimated that my trees would yield about 4 tons of olives, but Sunday, when I visited my orchard, I found the fruit would not be worth picking.

I killed some of the robins, and upon examination found as many as five or six whole olives in the crop of each bird. Besides those which the bird had swallowed whole, many olives are pecked so that they are spoiled for market. Sunday there were not less than 50,000 robins on my place, and they are equally as plentiful on El Quito farm.

Edward E. Goodrich, owner of the El Quito farm and olive orchard, quoted by the same authority, states:

The so-called robin is a destructive pest to an olive orchard. A crop can not be saved when the migration of the robin corresponds exactly with the maturity of the olive, as it does this year, except by immediate picking, which is practically impossible, or by shooting so constantly as to prevent steady consumption. * * * In 1898 my crop was 130 tons, and should have made about 4,000 gallons of oil. Owing to the lack of rain the result was about 2,750 gallons, of the value of $11,000. Now, that crop could have been wiped out in 10 days by robins if they had been here as they were this season and no shooting had been done. So far as my foreman could estimate, before the birds descended upon the place, he placed the crop at a probable 3,000 gallons, which means when sold from $12,000 to $16,000, according to prices, and that would have been utterly destroyed but for the constant shooting the last 10 days.

As it was, Mr. Goodrich placed his loss on the olive crop through the devastations of the robins at 25 per cent of the whole, or about $5,000.

The San Jose Mercury also states:

A representative of the Mercury visited the El Quito olive orchard to see what the facts were in this matter. He found a force of men picking the fruit as rapidly as possible, and he also saw thousands upon thousands of robins doing the same thing. On his way out he occasionally saw a single bird on the

fence or in a prune tree, but when he reached El Quito the sky was streaked with robins flitting about and having a gala time of it. Men were scattered about through the orchard with guns, and every few minutes the report of one of these would set the robins to flying, but in an instant they would settle down again and resume their feast.

Ellwood Cooper, of Santa Barbara, a prominent producer of olives on the Pacific coast, in a letter dated January 25, 1901, says:

The robin is a terrible pest to olives. The birds do not always appear to come to the coast. My first experience was some 15 years ago. The olives were late in ripening. I was as late as March making oil. The robins appeared to come in by the thousands. My last orchard that year was about one-half mile in length. The pickers were at one end. I had a man with a gun at the other, but they would attack the middle, and when the gunner would reach them they would fly to the end he left. This year they have been particularly bad. My boys reported that the birds, mostly robins, picked more olives than they could. The foreman of the pickers told me that he had knocked from a tree one-quarter of a sack and went to dinner; when he returned not an olive was on the ground. I know that on the ground in one orchard where the rain had caused to fall as many olives as would fill a bushel basket, in a week not one would be seen. The robins do not seem to be able to pick the olives so rapidly from the trees, but peck at those that are commencing to dry, knock them to the ground, then get them. The birds at this writing are in all my orchards by the thousands. They do not appear every year. It has been my theory that the native berries in the Sierra some years are not in sufficient quantities for food.

In the last sentence Mr. Cooper has probably struck the root of the trouble. There is a crop of olives every year and the number of robins fluctuates little. Robins rarely attack olives because usually their native food abounds, but where this fails the hungry birds shift about until they find a substitute.

The most common complaints against the robin in the past have been on the score of eating cherries. Where a few trees are planted for family use it is not unusual for the birds to take all the fruit; especially is this the case in a village or the suburbs of a large town where wild berry-bearing shrubs have been destroyed. On farms distant from towns this seldom happens, though the birds are apt to take toll from the tree first to ripen its fruit. This seems to satisfy their taste for fruit, and after that they take only an occasional lunch. Reports are not wanting that the robin damages not only strawberries, blackberries, and raspberries, but also larger fruits, as pears, peaches, prunes, and grapes; but such cases are occasional and local and due to circumstances that also are occasional and local. In a region where fruit raising is new, pioneers in the business frequently suffer severe losses from birds that seem to be attracted by the novelty.

Of wild fruits properly so called the robin's dietary contains about 65 species, while the cultivated varieties amount to only about 10. The robin eats also seeds, but so few as plainly to show that they are not a favorite food. Of grain it eats rice, corn, oats, and wheat,

but in such small quantities as to prove that they are not greatly relished. Apparently robins never are satisfied for any length of time without fruit or berries. Sparrows, blackbirds, and many other species thrive on dry seeds; not so robins. If berries are not at hand they move on to seek them. Sparrows remain in the north in severe weather, even when the ground is deeply covered with snow, if they can obtain plenty of seeds for food; but robins require for northern winter quarters a swamp where cedar, smilax, holly, etc., promise both shelter and food.

The robin among birds is one of the most efficient disseminators of fruit seeds. While small seeds like those of the raspberry and strawberry pass directly through the alimentary canal, larger seeds, like the stones of cherries, dogwood, pepper berries, china berries, and hackberries, are disgorged after the pulp is digested. In the Southern States it is common to see rows of cedar trees along fences where seeds have been dropped by perching birds, and lines of trees often mark the site of a fence which has long since disappeared. Seeds that have passed through the alimentary canal of birds or other animals do not appear to have their vitality impaired, and it has even been asserted that they germinate more readily than those sown directly from the tree.

Following is a list of vegetable substances found in the food of robins and the number of stomachs in which found:

Saw palmetto (*Sabal serrulata*)	2
Western juniper (*Juniperus monospermum*)	2
Red cedar (*Juniperus virginiana*)	18
Common juniper (*Juniperus communis*)	3
Panic grass (*Panicum* sp.)	3
Pigeon grass (*Chætochloa* sp.)	3
Rice (*Oryza sativa*)	1
Corn (*Zea mays*)	8
Oats (*Avena sativa*)	2
Wheat (*Triticum vulgare*)	3
Carrion flower (*Smilax herbacea*)	2
Green brier (*Smilax bona-nox*)	15
Saw brier (*Smilax glauca*)	3
Cat brier (*Smilax* sp.)	17
Bay-berries (*Myrica carolinensis*)	6
Fig (*Ficus* sp.)	3
Western hackberries (*Celtis occidentalis*)	22
Mississippi hackberries (*Celtis mississippiensis*)	24
Hackberries unidentified (*Celtis* sp.)	8
Mulberries (*Morus* sp.)	19
Mistletoe berries (*Phoradendron californicum*)	3
Dock (*Rumex* sp.)	1
Pale persicaria (*Polygonum lapathifolium*)	3
Smart weed (*Polygonum* sp.)	1
Amaranth (*Amaranthus* sp.)	2
Pokeberries (*Phytolacca decandra*)	15
Stellaria (*Alsine* sp.)	1
Barberries (*Berberis vulgaris*)	1
Red bay (*Persea borbonia*)	1
Spice berries (*Benzoin benzoin*)	3
Sassafras (*Sassafras variifolium*)	1
Currants (*Ribes* sp.)	12
Apple (*Pyrus malus*)	8
Crab apple (*Pyrus diversifolia*)	1
Mountain ash (*Pyrus americana*)	7
Western June berries (*Amelanchier florida*)	2
Alder-leaved June berries (*Amelanchier alnifolia*)	2
Service berries (*Amelanchier canadensis*)	12
June berries (*Amelanchier* sp.)	3

English hawthorn (*Cratægus oxycantha*)	2
Strawberries (*Fragaria* sp.)	6
Blackberries or raspberries (*Rubus* sp.)	47
Domestic cherries (*Prunus cerasus*)	34
Domestic prunes (*Prunus domestica*)	2
Wild black cherries (*Pruns serotina*)	28
Chokecherries (*Prunus virginiana*)	12
Bird cherries (*Prunus pennsylvanica*)	8
Cherries unidentified (*Prunus* sp.)	7
China berries (*Melia azederach*)	58
Wood sorrel (*Oxalis* sp.)	1
Staghorn sumac (*Rhus typhina*)	3
Smooth sumac (*Rhus glabra*)	19
Dwarf sumac (*Rhus copallina*)	10
Poison ivy (*Rhus radicans*)	3
Small-leaved sumac (*Rhus microphylla*)	1
Sumac unidentified (*Rhus* sp.)	12
Pepper berries (*Schinus molle*)	20
American holly (*Ilex opaca*)	19
Deciduous holly (*Ilex decidua*)	12
Black alder (*Ilex verticillata*)	3
Holly unidentified (*Ilex* sp.)	6
Strawberry bush (*Evonymus americana*)	2
Burning bush (*Evonymus* sp.)	1
Roxbury waxwork (*Celastrus scandens*)	2
Supple Jack (*Berchemia volubilis*)	9
Cascara sagrada (*Rhamnus purshiana*)	1
Woodbine (*Psedera quinquefolia*)	21
Northern fox grape (*Vitis labrusea*)	1
Summer grape (*Vitis æstivalis*)	1
Frost grape (*Vitis cordifolia*)	1
California wild grape (*Vitis californica*)	1
Unidentified grapes (*Vitis* sp.)	17
Flowering dogwood (*Cornus florida*)	59
Rough-leaved dogwood (*Cornus asperifolia*)	3
Panicled cornel (*Cornus paniculata*)	3
Alternate-leaved cornel (*Cornus alternifolia*)	1
Black gum (*Nyssa sylvatica*)	11
Tupelo (*Nyssa aquatica*)	6
Huckleberries (*Gaylussacia* sp.)	4
Small cranberries (*Vaccinium oxycoccus*)	2
Blueberries (*Vaccinium* sp.)	42
Persimmons (*Diospyrus virginiana*)	22
Olives (*Olea europæa*)	1
Button weed (*Diodia teres*)	2
Japan honeysuckle (*Lonicera japonica*)	1
Snow berries (*Symphorocarpos racemosa*)	4
Arrow-wood berries (*Viburnum dentatum*)	3
Black haw (*Viburnum prunifolium*)	2
Viburnum unidentified (*Viburnum* sp.)	1
Black elderberries (*Sambucus canadensis*)	8
Red elderberries (*Sambucus pubens*)	2
Elderberries unidentified (*Sambucus* sp.)	5
Common ragweed (*Ambrosia artemisiifolia*)	1
Other ragweeds (*Ambrosia* sp.)	7
Sunflower (*Helianthus* sp.)	1
Dandelion (*Taraxicum* sp.)	3
Fruit not further identified	71

Before dismissing the subject of vegetable food it is of interest to note that seeds of the California poison oak (*Rhus diversiloba*) were not found in the stomachs of west-coast robins. This appears the more singular when it is noted that the birds feed freely upon other species of *Rhus*; that this species is one of the most abundant shrubs in California, and in full fruit in the wintertime, when the robins are there; and that it is a favorite food of many species of winter birds. As the seeds of this plant are either regurgitated by birds or

passed uninjured, it follows that birds are the most efficient disseminators of these noxious shrubs. This is one evil of which the western robins apparently are guiltless, though the eastern ones eat a few seeds of the poison ivy.

Among the stomachs examined were those of a few nestlings about half grown. Their food was not found to differ essentially from that of the adults except, perhaps, that the predominance of animal matter was more pronounced, and any great number of stomachs would have shown a considerably higher percentage. One somewhat peculiar feature of the stomach contents was a "wad" of grass or other vegetable fibers in a close tangle and large enough to half fill the stomach. This was found in nearly every stomach of the nestlings, and has also occasionally been observed in the stomachs of young of other species.

Summary.—While the animal food of the robin includes a rather large percentage of useful beetles, it is not in the consumption of these or any other insect that this bird does harm. A bird whose diet contains so large a percentage of fruit, including so many varieties, may at any time become a pest when its natural food fails and cultivated varieties are accessible. While the robin to-day probably is doing much more good than harm, it must be acknowledged that the bird is potentially harmful. In New Jersey it has been protected for years by law and also by public opinion, while the native berry-bearing shrubs have been destroyed and their places filled by domestic varieties; consequently the birds have been obliged to resort to cultivated fruits for food, while fruit growers have seen the berry crop, their principal source of income, disappear. It is not probable that individually fruit growers have derived benefit enough from the birds' insectivorous habits to counterbalance the loss suffered through their agency. Briefly, the conditions are: Too many birds of a single species and too little of their natural food. Under such circumstances there is no doubt that a law allowing the fruit grower to protect his crop when attacked by birds would be proper.

In California conditions are somewhat similar though differing in detail. The canyons and hillsides normally supply robins with their winter food. This, however, sometimes fails, especially since the hill and canyon lands have been cleared to bring them under cultivation as orchards and farms. It is not surprising that robins accept olives as a fair substitute for the *Madrona*, *Heteromeles*, and *Cascara* berries taken from them. Here again is found the very undesirable condition of too many birds of a single species collected in a limited area. They all demand the same kind of food, and when it fails the birds seek till they find an acceptable substitute. It is usually preferable to supply the food they desire, and for which they will amply pay, instead of killing the birds.

VARIED THRUSH, OR OREGON ROBIN.

(*Ixoreus nævius* and subspecies.)

The varied thrush, or Oregon robin, in its two subspecies ranges over the northwestern coast region as far north as Alaska and as far south as northern California. One subspecies, *Ixoreus nævius nævius*, is found from northern California to southeastern Alaska, and the other, *Ixoreus nævius meruloides*, from northwestern Canada to central and western Alaska. In winter the two subspecies move southward to southern California. As the country which it inhabits has been settled only in comparatively recent times the bird has not yet become very domestic. It is usually rather shy and much of the time keeps in the tops of trees. Eminently a forest or ravine bird, it prefers the darkest cover. While much resembling the robin in form and color it widely differs from it in demeanor. A 10-acre orchard is none too large for a robin's activities, while a hundred varied thrushes might occupy a similar area and no one would suspect their presence. They venture about houses occasionally, but always retreat at the first sight of human life.

The Oregon robin apparently consumes the least animal food of any member of the family. Eating a very few of many kinds of insects, it never gets a large percentage of any one kind. However, knowledge of the food of this bird is derived from the examination of stomachs taken in winter, whereas stomachs secured in the breeding season might lead to entirely different conclusions.

Although this bird is so shy and inhabits cultivated country during only the colder season, it has in some places made itself offensive by its attacks on cultivated crops.

In a letter from John M. Edson, dated at New Whatcom, Wash., May 8, 1899, it is stated:

> Numerous reports have come to me from farmers hereabouts corroborative of the statement of the inclosed newspaper clipping with reference to "Oregon robins" working havoc among the pea fields, where it is alleged acres of ground have been divested of seed by them. It is said they appear in large number, sometimes as many as 200 in a flock. The bird pulls up the pea by the sprout, which it breaks off devouring the kernel. * * * The allegations go so far in some instances as to accuse the birds of destroying other grain as well.

The newspaper clipping referred to is from the Seattle Times of May 4, 1899, and says in part:

> A new fruit and farm pest has appeared in western Washington, to the great detriment and loss of the farmers and fruit growers. A variety of the common brown thrush, which is known on this coast as the Oregon robin, is making sad havoc of the pea acreage in Whatcom and Skagit Counties. Farmers in these counties raise a great deal of peas and feed to hogs. The birds lay hold of the peas as soon as they peep from the ground and, pulling up the peas by the shoot, eat it.

This is a serious accusation. It is a common experience that where a country is newly settled or new crops are introduced crops are liable to attacks by birds, which appear to be attracted by the novelty of the unknown food. However, as 15 years have elapsed since the above letter was written, and as no corroborative report has since been received, it is fair to infer that the damage that year was due to unusual conditions.

Food.—The varied thrush appears to be a pronounced ground feeder, and the stomachs show an unusual quantity of such food as thousand-legs, sow bugs, snails, and angleworms; but spiders are rarely eaten. Only 58 stomachs of this thrush were available for examination, and these were taken in the months from October to April, inclusive. This leaves us in entire ignorance of the summer food. Analysis shows 25.85 per cent animal food to 74.15 per cent vegetable.

Animal food.—Useful beetles, mostly predaceous ground-beetles, amount to 1.87 per cent of the food. Beetles altogether aggregate only 4.46 per cent. They belong to about a dozen of the most common families with no great preponderance of any. Ants comprise 4.08 per cent of the food, and other Hymenoptera (bees and wasps), 2.24 per cent. Hemiptera (bugs) amount to 1.09 per cent; Diptera (flies), 1.47 per cent; Lepidoptera (caterpillars), 2.18 per cent; Orthoptera (grasshoppers and crickets), to 1.99 per cent; and all other insects, 1.18 per cent. None of these groups of insects attracted the bird's special attention during the months in which these stomachs were collected. Spiders also fail to please, as they were found only in the stomachs collected in two months and amount to only 0.10 per cent. Myriapods (thousand-legs) seem to be more highly relished, as they are taken to the extent of 3.08 per cent. Earthworms, snails, and sow bugs collectively amount to 3.97 per cent, and their presence in the stomachs explains why the bird so commonly frequents dark, shady brooks and springs. The food of the varied thrush thus widely differs from that of other members of the family in the small proportion of insects in the diet and in the comparatively large percentage of mud-inhabiting creatures, as angleworms, snails, etc.

The following beetles were the only insects that could be identified except as to family:

COLEOPTERA.

Quedius capucinus	1	*Aphodius* sp	2

Vegetable food.—The vegetable food of the varied thrush consists of fruit, weed seed, and mast, with some unidentifiable matter. In eating weed seed and mast the bird widely differs from other species of the family. Cultivated fruit, mostly waste or left over, amounts

to 3.63 per cent for the season, and apparently consisted of apples, prunes, etc., left to dry upon the trees. Though no stones were found, some of the pulp appears to be of olives, and any olives consumed through the winter would, of course, be a loss to the grower. While the stomachs were not collected in the fruiting season eight species of wild fruit were identified. This comprised 23.21 per cent of the food and was found in every month in which stomachs were taken except April. The maximum amount, 73.67 per cent, is eaten in October when the bird returns from its summer home and wild berries are still on the bushes. Mast was perhaps the most unexpected food in the stomach of the varied thrush and was made up mostly of acorns. This item first appears in the stomachs taken in November, when it amounts to 76.71 per cent of the food. It decreases to the end of the season, except that none was found in four stomachs taken in February.

The habit of eating mast has undoubtedly developed from the fact that in the bird's winter residence acorns are abundant, fresh fruit not at all, and insects only in moderate numbers. The aggregate for the season is 18.86 per cent. Weed seed, another article of food too dry and hard for most thrushes, is eaten by the varied thrush to a very considerable extent during the four months from December to March. The average for each of those months is 16.78 per cent, but for the whole seven months is only 9.59 per cent. Miscellaneous articles of vegetable diet, such as seeds of sumac, poison oak, and ground up unidentifiable vegetable matter, amount to 17.18 per cent of the food. Rubbish, which completes the account, was found in several stomachs and amounts to 1.68 per cent.

Following are fruits, seeds, etc., identified, and the number of stomachs in which each was contained:

Juniper berries (*Juniperus* sp.)	1
Wheat (*Triticum vulgare*)	1
Amaranth (*Amaranthus* sp.)	1
Apple (*Pyrus malus*)	3
Blackberry or raspberry (*Rubus* sp.)	1
Filaree (*Erodium* sp.)	1
Pepper berries (*Schinus molle*)	1
Poison oak (*Rhus diversiloba*)	1
Sumac (*Rhus* sp.)	1
Buckthorn (*Rhamnus* sp.)	1
Black nightshade (*Solanum nigrum*)	1
California honeysuckle (*Lonicera hispidula californica*)	2
Round-leaved snowberry (*Symphorocarpos rotundifolia*)	1
Common snowberry (*Symphorocarpos racemosus*)	5
Fruit not further identified	8
Mast	16
Seeds unidentified	10

Summary.—From what is known of the insect food of the varied thrush, it does not appear that the bird is likely to do much mischief by eating useful insects. It takes but few, and these are so well distributed through the different orders and families that apparently no one species is unduly preyed upon. Quite a good portion of the animal food consists of creatures of little or no economic

significance, as snails, sow bugs, and other inhabitants of wet, dark coverts. The bird does not at present spend the breeding season in a well-settled and cultivated country, and so does not overmuch trespass upon farm products. Only one report of damage has been received, but as that was a number of years ago it is probable that conditions at that time were exceptional.

EASTERN BLUEBIRD.

(*Sialia sialis* and subspecies.)

In the breeding season the range of the eastern bluebird (*Sialia sialis sialis*) covers the whole of the United States eastward of the base of the Rocky Mountains and extends into Canada. It winters as far north as Pennsylvania and southern Illinois. The azure bluebird (*Sialia sialis fulva*), a subspecies, replaces the eastern form in southern Arizona, and ranges farther south into Mexico. Naturally

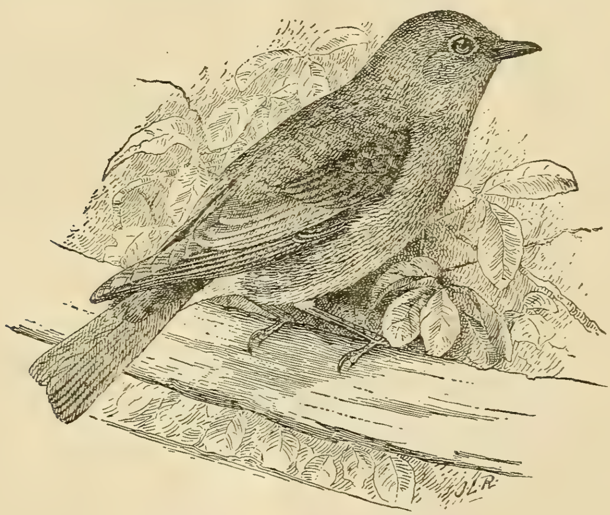

FIG. 2.—Bluebird (*Siala sialis*).

very domestic, the bluebird likes to build its nest in a cranny of a building, a box placed for its accommodation, or a natural cavity of a tree—preferably in an orchard. Deserted woodpecker holes or holes running down the center of old stumps are favorite places. Former nesting sites of bluebirds have in many instances been usurped by English sparrows, and many bluebirds thus driven away have betaken themselves to localities less settled and less frequented by the sparrow, where they can live and breed in peace. The bluebird is such an early spring migrant that many are overtaken by late snowstorms and perish. As a harbinger of spring it receives a kindly welcome, and boxes are often placed for its nest on buildings

or posts where it is safe from cats and other prowlers. The bird has never been accused, in the writer's knowledge, of depredations upon cultivated crops or of making itself obnoxious in any way. Its food consists largely of fruit obtained from pastures, swamps, and hedgerows, rather than from gardens and orchards. It is a prolific breeder, rearing from four to six young in each brood, and usually bringing off two and frequently three broods a year. Some observers assert that the young of the first brood assist in feeding later broods.

Food.—For studying the food habits of the eastern bluebird 855 stomachs were available. They had been taken in every month of the year and in 28 States, the District of Columbia, and Canada. The food consisted of 68 per cent animal and 32 per cent vegetable matter.

Animal food.—The animal food is made up, for the most part, of insects, with a few spiders, still fewer myriapods, and a mere trace of other forms. Beetles constitute the second largest item of animal food and for the year average 20.92 per cent of the diet. Of these, 9.61 per cent are useful species, mostly predaceous ground beetles (Carabidæ). Few birds exceed this record of destruction of useful beetles. The bluebird eats them every month in such quantities as to indicate that they are an agreeable article of food. The maximum consumption, 19.51 per cent, occurs in May, and the minimum, 2.94, in September. This destruction of useful beetles has been considered by some writers a blot upon the fair name of the bluebird. The present writer, however, holds that a thorough study of the relations of birds and insects will demonstrate that the more omnivorous a bird is in its insect diet the more useful it is; that is, the most useful birds are those that impartially attack all species of insects available and thus tend to maintain a balance in insect life without exterminating one species or allowing another to become overabundant.

Beetles of the May-beetle family comprise 5.54 per cent of the diet, and while taken to some extent in every month, more than half are eaten in the three months from April to June. They consist mostly of *Lachnosterna* and small dung beetles (*Aphodius*). Weevils or snout-beetles, eaten but sparingly, amount to only 1.06 per cent for the year, and in the month of greatest consumption, February, they reach only 2.95 per cent. Various other beetles, all of a more or less harmful nature, amount to 4.71 per cent.

Ants in the diet of the bluebird amount to 3.48 per cent, a greater percentage than that of the robin. Other Hymenoptera (wasps and bees) amount to only 1.62 per cent, but it must be borne in mind that the bluebird is not especially active on the wing. Remains of a worker honeybee (*Apis mellifera*) were found in one stomach.

Diptera (flies), like Hymenoptera, are quick of wing and not easily taken either in midair or sitting; consequently they, too, enter lightly into the diet of the bluebird, the total for the year being only 0.26 per cent; they do not amount to 1 per cent in any month and are entirely missing in four. Hemiptera (bugs) are eaten in moderation every month. In July they amount to 6.49 per cent and in March 6.01 per cent, the highest two points of the year. The average for the 12 months is only 2.75. While a number of families were represented, the Pentatomidæ, or stinkbugs, predominated. Remains of chinch bugs (*Blissus leucopterus*) were found in one stomach.

Lepidoptera (caterpillars, with a few moths) form an important and regular article of food of the bluebird. The greatest consumption, 18.82 per cent, occurs in March, and the least, 4.58 per cent, in December. Most of these insects were of the family Noctuidæ or owlet moths whose larvæ are the well known cutworms, though a few belonged to the Arctiidæ of which the larvæ are hairy caterpillars. One of these, *Spilosoma virginica*, the yellow bear, was identified in three stomachs. The average consumption for the year is 10.48 per cent, the third greatest article of animal food.

Orthoptera (grasshoppers, crickets, and katydids) furnish the largest item of animal food, amounting to a good percentage in every month, and in August and September aggregating 52.68 and 53.47 per cent, respectively. The month of least consumption is January, when they amount to 5.98 per cent, and the average for the whole year is 22.01 per cent. The number eaten in each month is about proportionate to their abundance. Orthoptera are evidently a preferred food and sought for at all times. They were found in 423 stomachs and were the sole contents of 19. In only four months does the quantity eaten fall below 15 per cent of the whole food. Most insects of this order are harmful and when abundant are very destructive. Fortunately most birds are fond of these insects and eat them freely whenever obtainable, and some species not at other times remarkably insectivorous eat grasshoppers when they are superabundant.

A few insects of other orders were eaten very irregularly and amount to only 0.34 per cent of the food. Spiders, more relished by the bluebird than by the robin, constitute a fairly large percentage of the food from March to July, but are taken to some extent every month; the average for the whole year is 4.37 per cent. Myriapods (thousand-legs), which seem to be eaten whenever they appear in the open, were contained in small quantities in the stomachs taken in every month but two. The average for the year was 1.20 per cent. The remainder of the animal food (0.57 per cent) consisted

of sow bugs, snails, and angleworms, with a few bones of lizards, tree frogs, etc.

Following is a list of insects and other animals identified in the stomachs of the eastern bluebird, and the number of stomachs in which found:

HYMENOPTERA.

Aphænogaster fulva	1
Tiphia sp	1
Anthophora sp	1
Bombus sp	1
Apis mellifera	1

COLEOPTERA.

Cicindela graminea	1
Cicindela repanda	1
Cicindela punctulata	2
Omophron labiatum	1
Omophron nitidum	1
Omophron americanum	1
Omophron sp	1
Carabus mæander	1
Carabus vinctus	1
Carabus sp	1
Dyschirius globulosus	1
Dyschirius æneus	1
Scarites subterraneus	1
Bembidium maculatum	1
Pterostichus lucublandus	2
Pterostichus femoralis	2
Amara elongata	1
Amara impuncticollis	11
Amara basilaris	1
Amara interstitialis	1
Amara obesa	1
Amara chalcea	1
Amara sp	1
Platynus punctiformis	2
Galerita janus	1
Chlænius pennsylvanicus	1
Chlænius tomentosus	1
Chlænius sp	1
Cratacanthus dubius	2
Agonoderus lineola	1
Agonoderus pallipes	4
Agonoderus sp	2
Harpalus viridiænus	1
Harpalus vagans	1
Harpalus pennsylvanicus	1
Harpalus herbivagus	1
Harpalus sp	3

COLEOPTERA—Continued.

Stenolophus sp	1
Anisodactylus rusticus	4
Anisodactylus nigrita	1
Anisodactylus opaculus	1
Anisodactylus agricola	3
Anisodactylus sp	3
Coptotomus longulus	1
Xantholinus obsidianus	1
Scaphisoma punctulata	1
Hippodamia parenthesis	1
Anatis 15-punctata	1
Phelister subrotundus	2
Saprinus fraternus	1
Cytilus sericeus	1
Byrrhus sp	1
Lacon rectangularis	1
Monocrepidius auritus	2
Drasterius elegans	2
Drasterius dorsalis	1
Corymbites cylindriformis	3
Limonius griseus	1
Chauliognathus marginatus	1
Chauliognathus pennsylvanicus	3
Chauliognathus sp	2
Telephorus sp	1
Canthon lecontei	1
Onthophagus hecate	5
Onthophagus tuberculifrons	1
Onthophagus sp	6
Atænius cognatus	1
Aphodius fossor	2
Aphodius fimetarius	43
Aphodius ruricola	1
Aphodius granarius	1
Aphodius inquinatus	48
Aphodius sp	8
Bolboceras farctus	1
Geotrupes splendidus	1
Lachnosterna tristis	1
Lachnosterna sp	3
Anomala binotata	3
Anomala varians	2
Ligyrus gibbosus	2
Aphonus sp	1
Euphoria sepulchralis	1

COLEOPTERA—Continued.

Euphoria inda	3
Euphoria sp	1
Tetraopes tetraophthalmus	4
Chlamys plicata	1
Myochrous denticollis	3
Colaspis brunnea flavida	1
Zygogramma suturalis	5
Zygogramma disrupta	1
Zygogramma sp	1
Plagiodera viridis	1
Diabrotica vittata	1
Cerotoma trifurcata	1
Disonycha sp	1
Haltica chalybea	1
Epitrix cucumeris	1
Systena elongata	1
Spermophagus robiniæ	1
Tribolium ferrugineum	1
Crymodes discicollis	1
Notoxus anchora	1
Meloë angusticollis	1
Epicauta vittata	1
Epicauta lemniscata	1
Epicærus imbricatus	1
Anametis grisea	1
Tanymecus lacæna	3
Tanymecus confertus	2
Sitones lineellus	2
Sitones hispidulus	1
Sitones flavescens	1
Phytonomus punctatus	2
Macrops vitticollis	1
Macrops sp	3
Pissodes strobi	1
Pachylobius picivorus	1
Conotrachelus seniculus	1
Conotrachelus sp	1
Tyloderma baridium	1
Balaninus caryatrypes	1
Balaninus nasicus	2
Balaninus sp	2
Rhodobænus 13-punctatus	1
Sphenophorus sculptilis	1
Sphenophorus parvulus	3
Sphenophorus compressirostris	1
Sphenophorus venatus	1

COLEOPTERA—Continued.

Sphenophorus callosus	1
Sphenophorus sp	1

DIPTERA.

Gonia capitata	1
Drosophila sp	1

LEPIDOPTERA.

Hyperchiria io	1
Leucarctia acræa	3
Spilosoma virginica	3
Agrotis sp	5
Nephelodes violans	1
Nadata gibbosa	1

HEMIPTERA.

Agallia sp	1
Camirus porosus	1
Tetyra bipunctata	1
Cydnus communis	1
Apateticus maculiventris	1
Lygæus turcicus	1
Nysius angustatus	2
Blissus leucopterus	1
Alydus pilosulus	2
Sinea diadema	1
Camptobrochis sp	1
Corixa burmeisteri	1
Notonecta undulata	1

ORTHOPTERA.

Tettigidea lateralis	1
Hippiscus tuberculatus	1
Melanoplus femur-rubrum	1
Melanoplus bivittatus	1
Melanoplus atlanis	1
Udeopsylla nigra	1
Gryllus pennsylvanicus	1
Miogryllus saussurei	1

PLECOPTERA.

Perla sp	1
Nemoura sp	1

ARACHNIDA.

Phidippus sp	1

Vegetable food.—The vegetable portion of the eastern bluebird's food is largely fruit and mostly of wild species. Practically all of the domestic fruit taken was in June and July. Cherries and raspberries or blackberries were the only fruits really identified, though

some pulp may have been of cultivated fruit. The most important vegetable food of the bluebird is wild fruit. The maximum quantity is eaten in December, when it amounts to 57.64 per cent. January comes next, but after that month the amount decreases rather abruptly to zero in May. No fruit, either wild or domestic, was found in the 58 stomachs taken in that month, but after that time the amount taken increases rapidly to its maximum in December. The average for the year is 21.85 per cent. At least 38 species of wild fruits were identified and probably more were present but not recognizable. The fruit-eating period of the bluebird is not in summer when the fruit is fresh on the tree, but from October to February, inclusive, during which months three-fourths of its fruit eating is done. From this it appears that fruit is really the winter food of the bluebird, tiding it over until insects are again abundant and taking the place of seeds eaten by so many birds at this season.

Seeds, however, are eaten by the bluebird, but only occasionally and sparingly. Apparently taken in spring, fall, and winter when nothing better offers they average for the year only 0.67 per cent. There is nothing to fear from the bluebird on the score of its eating grain, for this food was found in only two stomachs, one taken in January and the other in July. The first contained two kernels of wheat and nothing else, and in the second was found what appeared to be the ground-up pulp of wheat; the total percentage for the year is 0.32 per cent.

Under the head of miscellaneous vegetable food are included the seeds of sumac, both the harmless and poisonous kinds; the seeds of the bayberry; and a little indeterminate vegetable refuse and rubbish. The average for the year is 7.84 per cent, but for the five months from October to February these constitute a very fair proportion of the food. At this time of year seeds of the poison ivy, the poison sumac (in New England called dogwood), and the other sumacs are usually abundant and seem to be relished by many winter birds.

Following is a list of the various articles of vegetable diet identified in the stomachs of eastern bluebirds and the number of stomachs in which found:

Red cedar (*Juniperus virginiana*)	15
Panic grass (*Panicum* sp.)	3
Pigeon grass (*Chætochloa* sp.)	1
Wheat (*Triticum vulgaris*)	1
Asparagus berries (*Asparagus officinalis*)	1
False Solomon's seal (*Smilacina racemosa*)	2
Green brier (*Smilax bona-nox*)	1
Round-leaved brier (*Smilax rotundifolia*)	1
Cat brier (*Smilax* sp.)	1
Bayberry (*Myrica carolinensis*)	28
Hackberry (*Celtis occidentalis*)	12
Southern hackberry (*Celtis mississippiensis*)	3
Mulberry (*Morus* sp.)	2
Mistletoe berries (*Phoradendron flavescens*)	8
Sorrel (*Rumex* sp.)	1
Smart weed (*Polygonum* sp.)	2
Amaranth (*Amaranthus* sp.)	1

Pokeberries (*Phytolacca decandra*)	23
Red bay (*Persea borbonia*)	2
Currants (*Ribes* sp.)	1
Hawthorn (*Cratægus* sp.)	1
Blackberries or raspberries (*Rubus* sp.)	19
Rose haws (*Rosa* sp.)	1
Wild black cherries (*Prunus serotina*)	4
Chokecherries (*Prunus virginiana*)	4
Bird cherries (*Prunus pennsylvanica*)	1
Other cherries (*Prunus* sp.)	1
Staghorn sumac (*Rhus typhina*)	10
Smooth sumac (*Rhus glabra*)	22
Dwarf sumac (*Rhus copallina*)	11
Poison sumac (*Rhus vernix*)	2
Poison ivy (*Rhus radicans*)	19
Dahoon holly (*Ilex cassine*)	3
Deciduous holly (*Ilex decidua*)	1
Black alder (*Ilex verticillata*)	2
Ink berry (*Ilex glabra*)	35
Other holly (*Ilex* sp.)	1
Strawberry bush (*Evonymus americanus*)	2
Roxbury wax work (*Celastrus scandens*)	6
Purple haws (*Condalia* sp.)	1
Woodbine (*Psedera quinquefolia*)	31
Sarsaparilla (*Aralia* sp.)	1
Flowering dogwood (*Cornus florida*)	30
Rough-leaved dogwood (*Cornus asperifolia*)	11
Panicled cornel (*Cornus paniculata*)	4
Alternate-leaved cornel (*Cornus alternifolia*)	2
Other cornels (*Cornus* sp.)	2
Black gum (*Nyssa sylvatica*)	4
Huckleberries (*Gaylussacia* sp.)	4
Blueberries (*Vaccinium* sp.)	15
Persimmons (*Diospyros virginiana*)	1
Night shade (*Solanum* sp.)	1
Button weed (*Diodia teres*)	1
Partridge berry (*Mitchella repens*)	1
Tree cranberry (*Viburnum opulus*)	1
Arrow wood (*Viburnum* sp.)	1
Black elderberries (*Sambucus canadensis*)	23
Ragweed (*Ambrosia* sp.)	6
Fruit not further identified	19
Vegetable refuse or rubbish	28
Seeds not further identified	10
Mast	1

Summary.—Examination and analysis of the food of the eastern bluebird fully justifies the high esteem in which the bird is held. It does not prey upon any product of husbandry or in any way render itself injurious or annoying. During spring and early summer, when strawberries, cherries, and other small fruits are at their best, the bird subsists upon insects to the extent of five-sixths of its food, and in this period it eats more insects than at any other time of the year; in short the fruit-eating period of the bluebird is from late fall to early spring, when insects are scarce and waste fruit is available. The one point that has been urged against the bird is that it destroys a number of predaceous beetles. The harm done in this, however, is more apparent than real.

WESTERN BLUEBIRD.

(*Sialia mexicana* subspecies.)

The western bluebird (*Sialia mexicana occidentalis*), a subspecies of the Mexican bluebird (*Sialia mexicana mexicana*), occupies the Pacific coast from central California to Washington, and east to

western Montana: another subspecies, the chestnut-backed bluebird (*Sialia mexicana bairdi*), is a bird of the Rocky Mountain and Great Basin region from Wyoming southward to northern Mexico; while a third form, the San Pedro bluebird (*Sialia mexicana anabelæ*), ranges from northern Lower California to southern California. The three forms will be treated together, and for convenience referred to as the western bluebird. It has the same gentle, quiet demeanor that characterizes its relative of the Eastern States and, although not quite so domestic, is much inclined to frequent orchards and the vicinity of farm buildings. While the eastern bluebird usually nests either in a hole of an orchard tree or in a box provided for its use, the western species has not fully abandoned forest trees as nesting sites and often may be found in lonely canyons or among hills far from the abodes of man. The orchards of the west coast are hardly old enough to offer many hollow trees as nesting places so attractive to this gentle friend. In time, however, this bluebird will without doubt become as domestic as the eastern species. In fact a nest was once found by the writer in a hollow tree in the home orchard of a ranch only a few rods from the house. The six young contained in this nest would seem to indicate that in fecundity the western species resembles its eastern cousin.

The western bluebird is less migratory than the eastern and does not entirely desert the United States in winter; so its good work is continuous. As insects are active in California in every month the bird is able to support life even without other food. Moreover, the bird renders a great economic service in the reduction of these pests at this season, for insects that live through the winter are the stock by which the species is perpetuated, and the destruction of a few at this time is equivalent to the death in summer of hundreds or even thousands.

Food.—For the investigation of the food of the western bluebird 217 stomachs were available. While the greater portion of these were collected in California a number are from Oregon, a few from British Columbia, and one from Texas. Every month in the year is represented, though several not so fully as desirable. The food was found to consist of 81.94 per cent animal to 18.06 per cent vegetable matter.

Animal food.—Useful beetles, mostly Carabidæ, with a few lady-birds (Coccinellidæ), were eaten to the extent of 8.56 per cent, a little less than the record of the eastern bluebird. Other beetles, all more or less harmful, amount to 15.44 per cent. No special preference for any family was shown. While ants constituted 5.38 per cent of the food, none were found in the stomachs taken in May or December, and they appear to be distributed rather irregularly; July, for instance, has nearly 19 per cent, and August only 1 per cent. Other Hymenoptera (wasps and bees) amount to only 1.26

per cent. No honey bees were found. Hemiptera (bugs) were found in the stomachs taken every month but April and August, but the quantity in each month varied greatly and irregularly. The average for the year is 6.38 per cent. A small quantity of black olive scales (*Saissetia oleæ*) were found in one stomach.

Caterpillars appear to be one of the western bluebird's favorite foods. These and a few adult moths were found in the food of every month except May, but as only two stomachs were taken in this month the omission is probably accidental. Their appearance in the stomachs is very irregular, but it would probably be more uniform if more stomachs were available. March is the month of greatest consumption (50.18 per cent), but August has nearly as much, and April and November are not far behind. The average for the year is 20.25 per cent. No special pest was identified, but practically all caterpillars are harmful.

Grasshoppers, which constitute the largest and most regular item of the western bluebird's food, are not eaten quite so freely as by the eastern bird, although in the Pacific coast region they can be obtained at all times of the year. The least consumption occurs in January, with 1.81 per cent of the whole food, and the greatest in May with 49.50 per cent. In the East the maximum of grasshopper eating with nearly all species of insectivorous birds is in August or thereabout. The average for the year with the western bluebird is 21.29 per cent, a little less than the record of the eastern species in a much shorter season.

Diptera (flies) are evidently not a favorite food of the western bluebird. In four months none were found, and in March, only, do they amount to 1 per cent; in that month they are eaten to the extent of 5.64 per cent of the diet, but the average for the year is only 0.72 per cent. A few other insects not included in the foregoing amount to 0.44 per cent. Spiders were found in the stomachs taken every month, but not in large quantities, the average for the year being 1.94 per cent. Myriapods (thousand-legs) were eaten still less than spiders. They appeared in the food of only five months, and amount to only 0.17 per cent. A few angleworms, snails, and sow bugs amount to 0.11 per cent, and complete the items of animal food.

Following is a list of the animal constituents of the western bluebird's food as far as identified, and the number of stomachs in which found:

HYMENOPTERA.	
Messor andrei (ant)	1
COLEOPTERA.	
Amara aurata	2
Silpha ramosa	1
COLEOPTERA—Continued.	
Hippodamia convergens	10
Coccinella californica	3
Lebasiella maculicollis	1
Vrilletta murrayi	1
Polycaon stouti	1

COLEOPTERA—Continued.

Aphodius granarius	3
Aphodius lividus	1
Aphodius inquinatus	5
Aphodius pardalis	1
Aphodius rubidus	3
Aphodius sp	10
Chrysomela sp	1
Eulabis pubescens	1
Blapstinus sulcatus	1
Blapstinus dilatatus	2
Blapstinus pratensis	1
Blapstinus pulverulentus	6
Blapstinus sp	4
Rhigopsis effracta	3
Sitones hispidiceps	1
Sitones hispidulus	1
Balaninus sp	1

HEMIPTERA.

Saisselia oleæ	1
Sinea diadema	1

Vegetable food.—The vegetable food of the western bluebird, like that of its eastern relative, consists largely of fruit, and mostly of the wild species of hillside and canyon. Grapes, which may have been cultivated, were found in 16 stomachs, all taken in late fall and winter. Rubus fruits (blackberries or raspberries) were found in 4 stomachs, prunes in 1, cherries in 1, and figs in 3. Most of these were taken in late summer or fall and do not indicate extensive ravages upon cultivated fruit. Of wild fruits, elderberries, found in 25 stomachs, appear to be the favorites. Mistletoe berries made up the entire contents of 7 stomachs, evidently a preferred article of diet when they can be obtained. Fruit altogether amounts to 14.79 per cent of the food and nearly all is either wild or waste. Weed seeds were eaten sparingly and irregularly, and amount to only 1.25 per cent of the food. No grain of any kind was found. A few odd items like poison oak and other Rhus seeds, with a little rubbish, make 2.04 per cent, and complete the vegetable food.

Following is a list of the various items of vegetable food, with the number of stomachs in which found:

Elderberries (*Sambucus* sp.)	25
California mistletoe (*Phoradendron californica*)	7
Dock (*Rumex* sp.)	1
Smartweed (*Polygonum* sp.)	2
Service bush (*Amelanchier alnifolia*)	2
Blackberry or raspberry (*Rubus* sp.)	4
Prune (*Prunus* sp.)	1
Cherry (*Prunus* sp.)	1
Grape (*Vitis* sp.)	16
Dwarf sumac (*Rhus copallina*)	2
Poison oak (*Rhus diversiloba*)	1
Pepper tree (*Schinus molle*)	2
Nightshade (*Solanum* sp.)	1
Figs (*Ficus* sp.)	3

Food of young.—Among the stomachs of western bluebirds examined were those of several nestlings about a week old. These were of interest as showing how large a proportion of animal food is given to the young. In one brood of six the only vegetable food found was a single piece of plant stem, probably given accidentally with other food, and properly classed as rubbish. The real food consists of grasshoppers and crickets, 90 per cent, and beetles, 3 per

cent, the remainder being made up of bugs, caterpillars, and spiders. In another brood of four, grasshoppers and crickets constituted 97.5 per cent of the food, and one stomach contained nothing else. The remains of 11 grasshoppers were found in one stomach and 10 grasshoppers, a cricket, and a beetle in another. The only vegetable matter in the four stomachs was a single seed of *Polygonum*.

Summary.—That the western bluebird is an eminently useful species is so patent that it hardly needs to be pointed out. Whatever harm fruit growers have suffered from birds, none can be laid at the door of the western bluebird.

MOUNTAIN BLUEBIRD.

(*Sialia currucoides.*)

The mountain bluebird occupies in general the United States from the Rocky Mountains westward. A bird of the higher altitudes, it comes to the low valleys only in winter or during the prevalence of severe snowstorms in the mountains. As settlements encroach upon its range it adopts the habits of the eastern species and utilizes unoccupied crannies for nesting sites. In this the bird is said to be modifying its distribution, for it frequently finds such favorable localities for its nest that it remains and breeds in the lower altitudes instead of retiring to the mountains as formerly.

Food.—Only 66 stomachs of this species were available for investigation and these were not very regularly distributed, none being collected in May and November and only one each in February and October. The contents consisted of 91.62 per cent animal matter to 8.38 per cent vegetable. This is the highest percentage of animal matter of any member of the thrush family herein discussed and is equal to some of the flycatchers. It consists almost entirely of insects and a few spiders. The vegetable food is made up of fruit.

Animal food.—Beetles collectively amount to 30.13 per cent of the food and make the largest item. Of these 10.05 per cent belong to the three useful families—predaceous ground beetles (Carabidæ), tiger beetles (Cicindelidæ), and ladybirds (Coccinellidæ). In these items the food of the mountain bluebird exceeds that of any other species of thrush previously discussed. Weevils or snout-beetles (Rhynchophora) were eaten to the extent of 8.11 per cent, the highest record for any American thrush. As these are all injurious insects and some of them the worst pests in the insect world, this record for weevil destruction in some measure offsets the eating of useful beetles. The remainder of the beetle food was of more or less harmful families.

Ants were eaten by the mountain bluebird to the extent of 12.51 per cent. This record is not exceeded by any other bluebirds or robins. They were taken rather irregularly and in July amount to

31.50 per cent, or nearly one-third of the whole food. They made up 64 per cent of the contents of the one stomach taken in October, indicating that they are acceptable food when found. Other Hymenoptera (bees and wasps) amount to 3.80 per cent, a record fully up to the average of thrushes in general. Like ants they were taken rather irregularly and the maximum, 11.50 per cent, occurs in July. Hemiptera (bugs) amount to only 3.89 per cent and are not a very regular article of diet. In July they amount to 23.75 per cent, which is more than the combined amount for all other months. This record resulted from the fact that the contents of two stomachs collected in that month consisted almost entirely of small cicadas. Besides these, stinkbugs, negro bugs, assassin bugs, and jassids were taken. Diptera (flies), almost conspicuous by their absence, were found in the stomachs collected in April and September only, and amount to only 0.92 per cent for the year.

Lepidoptera (mostly caterpillars) are a rather regular article of food, amounting to 14.45 per cent for the year and constituting a large part of the food of every month in which stomachs were collected. In April they amount to 22 per cent and in September, in two stomachs taken, 48 per cent. It is probable, however, that the maximum consumption occurs in the early summer months. Orthoptera (grasshoppers, locusts, and crickets) are, next to beetles, the largest item of the food. Very curiously January shows the greatest consumption, 70.33 per cent; August, the normal grasshopper month, stands next with 53.86 per cent. The season seems to open in January and holds out with a good percentage in every month until it ends abruptly with 38.50 per cent in September. The average for the year is 23 per cent. This is higher than the record of any other thrush, though the other two bluebirds do not fall far behind. A few of the rarer insects, some spiders, thousand-legs, and a tick make up the rest of the animal food, 2.92 per cent.

Following is a list showing the insects identified and the number of stomachs in which found:

COLEOPTERA.

Amara interstitialis	1
Harpalus ellipsis	1
Silpha opaca	1
Hippodamia convergens	1
Syncalypta sp	1
Cardiophorus luridipes	1
Onthophagus sp	1
Aphodius fimetarius	1
Aphodius inquinatus	1
Dichelonycha sp	1
Chrysomela lunata	1

COLEOPTERA—Continued.

Centrioptera muricata	1
Thecesternus sp	2
Eupagoderes sp	1
Rhigopsis effracta	5
Trichalophus alternatus	1
Macrops sp	1

HEMIPTERA.

Zelus venardii	1
Sinea diadema	1

Vegetable food.—As with most of the other thrushes, the vegetable portion of the food of the mountain bluebird consists principally of small fruit. The currants and grapes found were in all probability domestic varieties, but as the grapes were from stomachs taken in December and January, and the currants from one taken in April, they can have but little economic significance.

Following is a list of the various items of vegetable food and the number of stomachs in which found:

Currants (*Ribes* sp.)	1	Grapes (*Vitis* sp.)	5
Elderberries (*Sambucus* sp.)	1	Unknown seeds	1
Sumac seeds (*Rhus* sp.)	1	Rubbish	4

Summary.—The mountain bluebird has probably not yet come in touch with the products of husbandry extensively enough to demonstrate its real propensities, but the nature of its food does not indicate that there is much to be feared from the bird. In the season of fruit and grain it subsists mostly upon insects and eats fruit and other vegetable food only in the season when nothing but left-over and waste products can be obtained.

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WM. A. TAYLOR, Chief

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THE VARIETIES OF PLUMS DERIVED FROM NATIVE AMERICAN SPECIES

By

W. F. WIGHT, Botanist, Office of Horticultural and Pomological Investigations

CONTENTS

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March 13, 1915.

(PROFESSIONAL PAPER.)

THE VARIETIES OF PLUMS DERIVED FROM NATIVE AMERICAN SPECIES.[1]

By W. F. Wight.

Botanist, Office of Horticultural and Pomological Investigations.[2]

INTRODUCTION.

The development from the wild condition and the introduction into cultivation of the varieties of plums enumerated in the following pages have taken place within the last hundred years, much the larger proportion even within the past fifty years. For various reasons many of the varieties never attained more than a local reputation, while others did not remain long in general cultivation. There are sections of the country where selection must be exercised even with native species in order to secure a tree of sufficient hardiness to withstand the strain of increased production when placed under cultivation. Some are lacking in the quality of the fruit, others are too susceptible to fungous troubles to make them profitable, while doubtless many have been tried in regions adapted to the growing of varieties of Old World species, where the natives proved disappointing in comparison. Nevertheless, in other sections the natives will probably be the main dependence, either as pure species or as hybrids with Old World forms.

No other native North American fruit, with the exception of the grape, has given rise to so many varieties as the plum. Not all of these have been derived from the same wild species, and the varieties belonging to a given form are mainly the ones best adapted to the region in which the parent species is native. A knowledge of the

[1] A botanical discussion of the native species of plums is given in U. S. Department of Agriculture Bulletin No. 179, entitled "Native American Species of Prunus."

[2] This paper was prepared in 1911, while the writer was associated with the Office of Taxonomic and Range Investigations of the Bureau of Plant Industry.

Note.—This bulletin is of general interest, but especially to horticulturists engaged in studying varieties or doing work in plum breeding.

botanical affinities of a given variety is therefore a matter of much importance to both the nurseryman and orchardist, and for this reason the attempt has been made to identify each variety with its species. This has been done either by a study of material or by means of such descriptions as exist in horticultural literature in the case of varieties no longer known to be in cultivation or of which it has been impracticable for any other reason to secure material.

These pages also constitute a record of achievement in American pomology with a fruit the importance of which was long overlooked and the value of which, even at the present time, is recognized by comparatively few. Information is brought together concerning the parentage when known, and a record is made of the work of those who have concerned themselves with the improvement of this fruit. With few fruits is there an equal opportunity to record step by step the advance which has been made since the original of the first-named variety was brought from its wild thicket and planted in a garden.

GEOGRAPHICAL ORIGIN OF VARIETIES.

The varieties of native plums have mainly originated in the Mississippi Valley, the State of Iowa alone having furnished 175, while 74 have come from Minnesota and 44 from South Dakota. Among the Southern States a much larger number, 97, have originated in Texas than in all of the others combined. In most of the States, too, the varieties originated have been from the species native to the region. In Iowa, for instance, 138 belong to *Prunus americana*, leaving a comparatively small number belonging to species not native to the State. In Texas, also, three-fourths of the total number are either of the species growing within the State or hybrids one of the parents of which is native to the State. It is in these western and southern regions that the fruit of several of the species appears to reach its greatest perfection in the wild condition, and doubtless the greatest development under cultivation may be expected to take place here also.

The geographical origin of the different varieties is indicated more clearly in Table I, which is designed to show the number of varieties belonging to a given species that have originated in each State. The varieties originating from subspecies are included with the species, but the hybrids are given separately.

TABLE I.—*Plums belonging to different species, showing the number of varieties that have originated in each State of the United States and in Canada.*

State or section.	Americana.	Americana hybrids.	Nigra.	Mexicana.	Mexicana hybrids.	Hortulana.	Hortulana hybrids.	Munsoniana.	Munsoniana hybrids.	Angustifolia.	Angustifolia hybrids.	Besseyi.	Besseyi hybrids.	Maritima.	Subcordata.	Pumila hybrids.	Unclassified.	Total.
Alabama	....	....	....	....	....	....	....	1	....	....	....	....	....	....	....	....	3	4
Arkansas	....	....	....	....	....	2	....	1	....	....	....	....	....	....	....	....	....	3
California	....	....	....	....	....	....	....	....	....	....	....	....	....	....	2	....	12	14
Colorado	1	....	....	....	....	1	....	....	....	....	....	1	1	....	....	....	....	4
Canada, eastern	9	....	6	....	....	....	....	....	....	....	....	....	....	....	....	1	....	16
Canada, western	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	29	29
Florida	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	6	6
Georgia	....	....	....	....	....	....	....	1	....	2	1	....	....	....	....	....	....	4
Indiana	2	....	....	....	....	1	....	1	....	....	....	....	....	....	....	....	....	4
Iowa	138	6	1	....	....	9	1	13	2	....	....	....	....	....	....	....	5	175
Illinois	5	1	....	....	....	7	....	5	....	....	....	....	....	....	....	....	3	21
Kansas	7	....	....	....	....	....	....	....	....	2	1	....	....	....	....	....	2	12
Kentucky	1	....	....	....	....	4	....	1	....	....	....	....	....	....	....	....	....	6
Louisiana	....	....	....	....	....	....	....	1	1	4	....	....	....	....	....	....	4	10
Maryland	3	1	1	....	....	....	1	....	3	2	....	....	1	....	....	....	....	12
Minnesota	55	3	6	....	....	3	1	....	....	....	....	3	2	....	....	....	1	74
Mississippi	....	....	....	....	....	....	....	1	....	....	1	....	....	....	....	....	1	3
Missouri	2	....	....	....	....	5	....	7	....	2	....	....	....	....	....	....	2	18
Nebraska	19	10	1	....	....	6	....	4	5	....	....	....	4	....	....	....	4	53
New Jersey	....	....	....	....	....	....	....	....	....	....	....	....	....	3	....	....	....	3
New York	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1	1
North Carolina	....	1	....	....	....	....	2	1	5	....	4	....	....	....	....	....	....	13
Ohio	1	....	....	....	....	1	....	1	....	....	....	....	....	....	....	....	1	4
Pennsylvania	....	....	....	....	....	....	....	....	....	1	1	....	....	....	....	....	....	2
South Carolina	....	....	....	....	....	1	....	1	....	1	....	....	....	....	....	....	....	3
South Dakota	19	11	....	....	....	....	....	....	....	....	....	3	17	....	....	....	....	50
Tennessee	....	....	....	....	....	3	....	4	1	....	....	....	....	....	....	....	1	9
Texas	....	....	....	1	2	8	7	13	8	29	19	....	....	....	....	....	10	97
Vermont	4	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	4
Virginia	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1
West Virginia	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1
Wisconsin	13	....	3	....	....	....	1	....	....	....	....	....	....	....	....	....	....	17

PARENTAGE OF VARIETIES.

Comparatively few data appear to be available concerning the parentage of varieties, and in particular information is lacking as to what has served as either the seed or pollen parent of a given variety. Definite statements may be found indicating a direct wild origin for about 6 nigra, 50 americana, 7 hortulana, 3 munsoniana, and 15 angustifolia varieties, and probably the actual number introduced from the wild is somewhat greater in each case. A large majority of the varieties have originated under cultivation, yet, as stated above, exact statements concerning the seed or pollen parents of many of them do not appear to be available. What seem to be reliable accounts concerning the origin of varieties show Cheney to be the seed parent of 1 variety; De Soto of 12; Forest Garden, 2; Gold Coin, 1; Hammer, 1; Harrison, 15; Hawkeye, 10; Iowa Beauty, 1; Lottie, 2; Miner, 8; Poole Pride, 1; Pottawattamie, 1; Purple Yosemite, 1; Quaker, 2; Robinson, 1; Rollingstone, 3; Sioux, 1; Surprise, 1; Van Buren, 9; Wayland, 2; Weaver, 3; Wild Goose, 26; and Wolf, 4. So far as known, these parent varieties, with four exceptions, are of wild origin. These four exceptions are Hammer, which is a seedling of Miner; Hawkeye, a seedling of Quaker; Lottie,

a seedling of Van Buren; and Surprise, a seedling from an orchard of several named varieties. It is true some other varieties have been used more or less extensively in breeding work, but their progeny has either not been named or has not been disseminated sufficiently for their names to occur in nursery literature, and, so far as definite information is available, few varieties seem to be more than two generations from the wild. This condition is probably very different from what has taken place in the development of European varieties, a large number of which are doubtless several, probably many, generations removed from their original wild progenitor.

VARIETIES CLASSIFIED BY SPECIES.[1]

CLASSIFIED VARIETIES.

PRUNUS NIGRA.

Aitkin; Anderson No. 2; August; *Branden Ruby; *Canadian Apricot; Carstesen; Cheney; *Cherry; Crimson; *Eureka; Hanson; Itasca; Manitoba; Manitoba No. 4; *Mills Seedling; *Native Red; Odegard; Oxford; R. B. Whyte Nos. 1, 4, and 5; Smith Red; Snelling; Wazata.

PRUNUS AMERICANA.

*Admiral Schley; Advance; Alexander; Alexander Late; *Allen; Alpha-Americana; Anderson; *Anna; *Annual Bearer; *Apple; *Apricot; Atkins; Bailey; Baldwin; *Baraboo; *Barnsback; *Bean; Bender; Benson Market; *Berry Hill; *Beta No. 4; *Birchland; Bixby; Blackhawk; Bomberger; Bossland; Bounder; Brackett; *Brainerd; Brooklyn; Bruning; Bruning No. 2; Bryan; *Budd; Burdick; California; *Campbell (?); *Canary; Caneford; Captain Bacon; *Captain Watrous; *Caroline; Champion; Cherokee; *Chippewa; *Christie; City; Coinage; Collman; Colorado Queen; Comfort; Comptine; Cottrell; *Couler; *Crable; Craig; *Cyclone; Dahlgreen; Dakota; Davenport; Deepcreek; Dennis; Des Moines; De Soto; *Dewey; *Diamond; Diana; Dorothy(?); Douglas; Dunlap No. 1; *Dunlap Nut; *Early Minnesota; Early Vermont; Eaton; Eddie; *Edith; Eldorado; *Eldridge; *Emerson; Emma; Etta; Fairchild; Fitzroy; *Flora Plena; Forest Garden; *Freestone; Galena; *Gamma No. 6 (?); *Garden King; *Gates; Gaylord; *Gaylord Gold; Gem; *Goff; Gold (not the Gold of Stark Bros.); *Gold Coin; *Gold Colored; Golden Mammoth; Golden Queen; Grace; Guilford; *Guinea Egg; Haag; Harrison; *Harrison Large Red; Hart; Hartwick; *Harvest; Hawkeye; Heaton; Hiawatha; *Hillside; Hilltop; *Hilman; *Hinckley; Holt; *Homestead; Honey; *Hoskins; Hunt De Soto; *Huya; Ida; *Imperial; Iowa Beauty; Ironclad; Isaac; Isabella; Ivason; *Jessie; Joe Hooker; Jones; Jones Late; Julia; Kampeska; Kathrin; Keith; Kickapoo; Klondike; Knudson; Kober; Kopp; Lambert; Lang; *La Prairie; Large Red; Late Rollingstone; Le Duc; *Legal Tender; *Leonard; *Letta; Lillie; Little; Lizzie; Lockey; Lottie; Louisa; *Luedloff; *Luedloff Green; *Luedloff Red; Mackland; Macomber Nos. 1 and 2; *Manitoba Nos. 1, 2, and 5; Mankato; Marais des Cygne; *Marble; Marcellus; Marcus; *Marion; *Marjorie; Mary; Maud Lacey; *McKinley; *Meadow; *Melon; Meyer; Miller; *Millett; *Millett Early Red; Millett T. T.; *Millett Very Early Red; Minnesota Seedling; Minnetonka; *M. J. De Wolf; Mollie; *Monon; Monona; Moon; Moore's No. 1;

[1] No material of those varieties marked by an asterisk (*) has been seen by the writer, and they are referred to the species on the basis of available descriptions and information concerning their origin or on the authority of some horticulturist who has seen the variety. A mark of interrogation (?) indicates that positive identification could not be made.

Motteleigh; *Muldraugh; Muncy; *Mussey; *Neals; *Nebraska Wonder; Nellie; Nellie Blanche; *Neverfail; *New American; *Newton; Newton Egg; New Ulm; Nome; Norby; *Norby No. 1; *Norby No. 11; Noyes; Oatey; Ocheeda; Oglesby; Old Gold; *Olson; *Omega; Oren; Owatonna; *Parker (?); Patten B.; Peach; Peerless; Penning; Penning No. 1; Penning Peach; Pilot; Piper, Plunk; Potter; Premium; President; Price; Purple Yosemite; *Quality; Rareripe; Rebecca; Reche; Red Cloud; *Red Horse; *Redick; Reel; Richey Nos. 1 and 2; *Robert; Rockford; Rocky Mountain; Rocky Mountain Dwarf (?); Rollingstone; Rollingstone Late; *Roselle; Rue; Sada; *Sanderson; Schoenthal; September; Shanghai No. 2; Silas Wilson; *Sixby; Slow; Smith; *Snyder; Speer; Splendid; *Springer; Steinman; Stella; *Sterling; *Stickney; Stoddard; Sugar Plum; Sunrise; Swift; Tecumseh; *Terry De Soto; *Teton; *Throssel; *Tomlingson (?); *Topa; *Trostle; United States; *Value; Van Deman; Vermillion; *Violet (?); *Wagner; Wallace; Waraju; *Warner; Warren; *Wastesa; Weaver; Welch; Welcome; White Prune; Wier; Wier No. 50; Wildrose; Williams; Williams Nos. 17, 19, and 20; Wilson; Winnebago; Winnepeg; Witman; Wood; Worth; Wragg; Wyant; *Yellow Americana; Yellow Sweet; *Yellow Yosemite; *Yuteca; *Zekanta.

PRUNUS AMERICANA LANATA.

*Alice; American Eagle; Brittlewood; Brittlewood No. 3; *Caro; Consul; *Don; Gloria; Pearl; Quaker; Quaker Beauty; Reinette; Terry; Van Buren; Wolf; *Wolf Clingstone.

PRUNUS MEXICANA.

Buffalo Bill.

PRUNUS SUBCORDATA.

*Sierra; Sisson.

PRUNUS HORTULANA.

*American Golden; Aurora; Bales; Benson; Brogden's Prolific; Carver; Crimson Beauty; *Culberson; Cumberland; Dunlap; Eldora; Garfield; Golden Beauty; *Hoosier; Irby; Iris; Kanawha; Lakeside Nos. 1 and 2; *Langsdon; Leptune; Maranokita; *Mathews; *Missouri; Missouri Apricot; Moreman; *Peach Leaf; *Pontotoc; Reed; Sucker State; Wagner No. 15; Wayland; Worldbeater; *Yellow Oregon.

PRUNUS HORTULANA MINERI.

Bestovall; Bulah; Clinton; *Decker; *Dennis Seedling No. 3; Esther; Forest Rose; *Forest Rose Improved; Gale(?); Garber; *Guilford No. 2; *Harris(?); *Hilda No. 5; Indiana; Iona; Irene; Iris; *Iroquois; Maquoketa; Miner; Nebraska; Prairie Flower; Rachel; *Red Glass; Sunset.

PRUNUS MUNSONIANA.

*Amelia(?); Arkansas; Brunswick; *Butler; Charity Clark; *Clara; Cleveland; Clifford; *Curry; Davis; Dorsett; Downing; Drouth King; Estella(?); Eureka; *Fanning; Freeman; *Freestone Goose; *Harper(?); *Hoffman; Hollister; Hughes; Indian Chief; Jewell; Kicab; *King; *Late Goose; Macedonia; Miles; Milton; *Mississippi; *Modern Woodman; *Muncy; Newman; *Nolan; Ohio; Osage; *Oxheart; Pekin(?); Poole Pride; Pottawattamie; *Ramsey Last; Red October; Red Skin; Robinson; Roulette; Schley; *Shedd Cluster(?); Smiley; Tenneha; *Tennessee; Texas Belle; Thousand-and-One; *Tucker; *Tudor(?); *Underhill Seedling; Venice; Venus; Vick; Whitaker; Wild Goose; *Wild Goose Improved; *Wooster; Wooten; Wychoff; *Yellow Wild Goose(?).

PRUNUS ANGUSTIFOLIA.

Caddo Chief; Clark; Early Red; *Kelley(?); *McPherson(?); Ogeeche; Ragland.

PRUNUS ANGUSTIFOLIA VARIANS.

African; Black African; Clark; Cluck; Coletta; *Denton; *Early Honey; *Early Sweet; *Echo(?); Emerson (Bruce); *Everbearing(?); Fawn; *Golden Drop; *Hattie Porter; *Heep(?); *Heming(?); *Hendrick(?); Jennie Lucas; *Lindheimer; Lone Star; Mason; McCartney; *Mudson(?); Munson; Piram; *Red Chickasaw(?); Sanders; *Waddell; *Yellow Cherokee; *Yellow Chickasaw; Yellow Transparent.

PRUNUS ANGUSTIFOLIA WATSONI.

*Bluemont; *Clarendon; *Kansas Dwarf Sand Plum; *Large Purple; *Large Red; *Large Yellow; *Panhandle; Purple Panhandle; Quitaque; Red Panhandle; Strawberry; Welcome; Yellow Panhandle.

PRUNUS MARITIMA.

Alpha; Bassett; Beta.

PRUNUS BESSEYI.

*Champa; Heideman Black; Heideman Red; Heideman Yellow; Rocky Mountain Cherry; *Sioux; *Tomahawk.

PRUNUS PUMILA.

*The New Wonderful Dwarf Cherry Tree.

HYBRID VARIETIES.[1]

AMERICANA WITH ANGUSTIFOLIA WATSONI.

Laire (?).

AMERICANA WITH ARMENIACA.

*Yuksa.

AMERICANA WITH BESSEYI.

*Cheresoto; Pennock; *Sansota; Whatisit.

AMERICANA WITH HORTULANA.

Cook Choice (?); Profuse (?); *Reagan; Van Houten.

AMERICANA WITH HORTULANA MINERI.

Crescent; Hammer; Idall (?); North Star; *Pomona (?); Surprise; *Truro.

AMERICANA WITH MUNSONIANA.

Cooper; *Duke (?); Forewattamie; Hunt; Pendent.

AMERICANA WITH NIGRA.

*Kitty; Manitoba No. 6.

AMERICANA WITH SIMONII.

*Hanska; *Inkpa; *Kaga; Toka; Tokata.

AMERICANA WITH TRIFLORA.

Ames; *''BAQ'' (?); ''Burbank × Redick''; Bursoto; Combination (?) (Williams); Emerald; *Gaviota (?); *Leopard (?); Meneray (?); Omaha; *Oziya; Seper (?); *Wakapa; *Wohanka.

ANGUSTIFOLIA OR ANGUSTIFOLIA VARIANS WITH CERASIFERA.

*Doris; *Hattie (?); Marianna.

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[1] In this list all of the hybrids between two species are given under a single heading, irrespective of which species is the seed parent.

ANGUSTIFOLIA OR ANGUSTIFOLIA VARIANS WITH MUNSONIANA.

Beaty; Eagle; Emerson Yellow; Miller's No. 5 (?); Tarleton.

ANGUSTIFOLIA OR ANGUSTIFOLIA VARIANS WITH TRIFLORA.

*Adele; Bertha; *Biconical; *Breck; *Daisy; Excelsior (?); Franklin; Funk; Gonzales; Govalle; *Halcyon; Holland; Kelsaw; Margaret; Nona; Preserver; Ragland; Six Weeks; *Terrell; Watson; Yates.

ANGUSTIFOLIA WATSONI WITH BESSEYI.

Utah.

BESSEYI WITH CERASIFERA.

*Cistena; *Stanapa.

BESSEYI WITH CERASUS.

Montbessey (?).

BESSEYI WITH SIMONII.

*Tokaya.

BESSEYI WITH TRIFLORA.

*Enopa; *Etopa; *Eyami; *Ezaptan; *Sapa; *Skuya; *Wachampa.

BESSEYI WITH AMYGDALUS PERSICA.

*Kamdesa.

HORTULANA WITH HORTULANA MINERI.

*Marble; *Minco; *Presley; *Virgie.

HORTULANA WITH MUNSONIANA.

Choptank (?); *Ellis; *Gowa; Nimon; *Ollie; Sophie (?); Wilder (?).

HORTULANA MINERI WITH MUNSONIANA.

*Lancaster; *Ray.

HORTULANA WITH TRIFLORA.

Dayton; *Eggles; Pander; *Satin; Waugh.

MEXICANA WITH MUNSONIANA.

Grayson.

MEXICANA WITH REVERCHONII.

Ward October Red.

MEXICANA WITH TRIFLORA.

Bilona.

MUNSONIANA WITH CERASUS.

Goosedye.

MUNSONIANA WITH TRIFLORA.

Advance; Alabama; America; Apple; *Bonner; *Burford; *Dora; Golden; Goose-O; *Happiness; Juicy; *Lannix; *Minnie; Monolith; Red May; Ruby; *Scribner.

MUNSONIANA WITH AMYGDALUS PERSICA.

Blackman; Mule; *Southern Beauty.

PUMILA WITH AMERICANA.

*Rupert.

DERIVATIVE HYBRIDS.

*Alhambra; *Chicrigland; *Cikana; *Duarte; *Glow; *Kahinta; Maryland (?); *Okiya; *Opata; *Owanka; *Sirocco; Victor Sand Cherry.

UNCLASSIFIED HYBRIDS.

Black Beauty; Combination; Compass; First; *Florida Queen; *Georgia; Heideman No. 88; *Howe; Japex; *July Fourth; Louisiana; *Martha; *McRea; *Miller; North Carolina; Puzzle; *Ultra.

UNCLASSIFIED VARIETIES.

*Alberta; *Allie; *Arctic; *Assiniboia; *Assiniboin; *Bastle; *Bedford; *Bell; *Carpenter; *Centennial; *Charmer; *Chinook; *Clark's Everbearing; *Clemon's Seedling; *Coleman Late; *Columbia Wonder; *Cuba; *Daniel Weeping; *Dawson; *Eva; *Fin de Siecle; *First Sweet; *Fuller; *Gorman; Hope; *Houston County; *Ingels; *Iola; *Ithaca; *Kenyon; *Laura; Madam Leeds; *Meneray's No. 2; *Mountain Plum; *Musquaka; *Norman; *Ohio Chief; *Parrott; *Parson; *Pasqua; *Patten A; *Perryville; *Prairie Rose; *Queen of Arkansas; *Red Glass Junior; *Regina; *Rocky Mountain Seedling; *Round; *Saffold; *Sandoz; *Saskatchewan; *Shaker; *Simpson; *Souris; *South Cumberland; *Southern Golden; *Victor; *Victoria; *Wabash; *Wady; *Watts; *Waver Bright; *Wilmeth Late; *Wortham; *Wragg Freestone; *Wyandotte; *Yukon.

ORIGIN AND SPECIES OF NATIVE VARIETIES OF PLUMS AND OF HYBRIDS.

EXPLANATION.

The accompanying list of native varieties of plums and of hybrids is designed to give information concerning the origin of a given variety and the species to which it belongs. Of those varieties marked by an asterisk (*) no material has been seen by the writer, and such varieties have been referred to the species on the basis of other considerations than a study of the material. It is believed, however, that the disposition is reasonably correct and wherever there has been doubt as to the correct disposition of a variety it is so indicated or the name of the species is omitted entirely.

Information concerning the origin of the varieties is based on the statements given where the names were first published or on later statements of the originator or introducer, and the citations are to be found in Mr. U. P. Hedrick's recent work entitled "The Plums of New York." For those varieties not included in that volume, or where additional information has been found, a footnote refers to the publication in which it appeared. In a few instances the information has been secured by correspondence with the person from whom the material was obtained.

It has not been possible in all cases to secure material for study from the originator, and in order that the reader may form his own opinion regarding the authenticity of such material it is thought best to give its source. This is referred to by the numeral immediately following the name of the variety.

SOURCE OF THE MATERIAL STUDIED.

A list of the persons, institutions and localities furnishing the material studied in the preparation of the list of native varieties and hybrids follows.

1. S. G. Ayer, Fayetteville, N. C.
2. Baker Bros., Fort Worth, Tex.
3. Mr. Bales, Jackson, S. C.
4. E. Bartholomew, Stockton, Kans.
5. M. L. Black, Onawa, Iowa.
6. J. S. Breece, Fayetteville, N. C.
7. Brogden & Gorse, Springdale, Ark.
8. Benjamin Buckman, Farmingdale, Ill.
9. Carstesen Orchard, near Ottawa, Canada.
10. E. S. Goff, Madison, Wis.
11. R. A. Hunt, Euclid, Ohio.
12. Mr. Hunt, Nursery, Tex.
13. S. M. Irwin, Geneva, Kans.
14. J. W. Kerr, Denton, Md.
15. F. K. McGinnis, Terrell, Tex.
16. Gilbert Onderdonk, Nursery, Tex.
17. Martin Penning, Sleepy Eye, Minn.
18. Pennock Nursery & Seed Co., Fort Collins, Colo.
19. A. M. Ragland, Pilot Point, Tex.
20. F. T. Ramsey, Austin, Tex.
21. D. N. Shoemaker, Takoma Park, D.C.
22. G. H. Spear, Greeley, Colo.
23. C. Steinman, Mapleton, Iowa.
24. F. A. Waugh, Amherst, Mass.
25. G. H. Wilson, Hustisford, Wis.
26. M. J. Wragg, Waukee, Iowa.
27. Arlington Farm, Virginia.
28. Central Experimental Farm, Ottawa, Ontario.
29. Georgia Agricultural Experiment Station, Experiment, Ga.
30. Iowa Agricultural Experiment Station, Ames, Iowa.
31. Michigan Agricultural Experiment Substation, South Haven, Mich.
32. Minnesota Agricultural Experiment Station, St. Paul, Minn.
33. Missouri Agricultural Experiment Station, Columbia, Mo.
34. New York Agricultural Experiment Station, Geneva, N. Y.
35. Oregon Nursery Co., Hillsboro, Oreg.
36. South Dakota Agricultural Experiment Station, Brookings, S. Dak.
37. Washington Agricultural Experiment Station, Pullman, Wash.
38. Boerne, Tex.
39. Colfax, Ind.

ABBREVIATIONS USED IN DESIGNATING THE SPECIES.

The following abbreviations are used in designating the species of plums in the list of native varieties and hybrids:

am..........americana.
am l........americana lanata.
an...........angustifolia.
an v........angustifolia varians.
an w........angustifolia watsoni.
ar...........armeniaca.
b............besseyi.
c............cerasifera.
c a.........cerasifera atropurpurea.
d............domestica.
h............hortulana.
h mi........hortulana mineri.
ma..........maritima.
me..........mexicana.
mu..........munsoniana.
n............nigra.
p............pumila.
r............reverchonii.
s............simonii.
su..........subcordata.
tr...........triflora.
A. persica..Amygdalus persica.
A. texana..Amygdalus texana.

ALPHABETICAL LIST OF NATIVE VARIETIES AND HYBRIDS.

The following list of native varieties and hybrids shows the origin of each variety and the species to which it belongs, as already explained:

*Adele, (tr × an) × tr. Offered in 1911 by M. A. Yates, Brenham, Tex., who states that it is Nona crossed with Abundance.

Admiral Dewey. See DEWEY.

***Admiral Schley**, am. Originated under cultivation with H. A. Terry, Crescent, Iowa, in 1897, and said by Craig and Vernon to be *americana*.

Advance, 14, am. Originated by Theodore Williams, Benson, Nebr.

Advance, 20, tr × mu. A variety from F. T. Ramsey.[1]

African, 14, an v. Originally from Dewitt County, Tex., and introduced in 1870 by G. Onderdonk, Nursery, Tex.

Aitken. See AITKIN.

Aitkin, 28, 32, 36, n. Found wild in Aitkin County, Minn., by D. C. Hazleton, and introduced in 1896 by the Jewell Nursery Co., Lake City, Minn.

Alabama, 34, tr × mu. A Japan hybrid originated by J. L. Normand, Marksville, La.

***Alberta**.[2] A seedling raised at the Indian Head Experimental Farm, Saskatchewan.

Alexander, 30, am. Originated with J. W. Alexander, Saline County, Nebr. Offered by the Brock Nurseries, Brock, Nebr., in 1902 or 1903.

Alexander Late. See ALEXANDER.

***Alhambra**, [[(tr × c) × d] × (s × tr)] × (am × n) (?). Originated by Luther Burbank, Santa Rosa, Cal., and the pedigree is given by De Vries [3] as Kelsey crossed with Pissardi, this hybrid being crossed with French prune, the resulting hybrid crossed with a hybrid of *simonii* and *triflora*, and this again crossed with a hybrid of *americana* and *nigra*.

***Alice**, am l. A seedling of Van Buren, originated by H. A. Terry, Crescent, Iowa, and without doubt *americana lanata*, like the seed parent.

***Allen**, am. A variety of Kansas origin and believed by F. A. Waugh to be an *americana*.

Allen's Yellow. See ALLEN.

***Allie**. A seedling raised at the Indian Head Experimental Farm, Saskatchewan.

Alpha, 14, ma. Selected from the natural habitat of the species in New Jersey by E. W. Winsor and introduced by J. W. Kerr, Denton, Md., in 1899.

***Alpha-Americana**, am. A seedling of De Soto pollinated by Weaver, originated by N. K. Fluke, Davenport, Iowa, in 1890.

***Amelia**, mu (?). A variety offered by N. W. Craft, Shore, Yadkin Co., N. C., and said to resemble Wild Goose.

America, 34, mu × tr. Originated by Luther Burbank, Santa Rosa, Cal., who states that it is Robinson crossed with Botan [Abundance].

American Eagle, 14, 36, am l. Introduced in the fall of 1889 and spring of 1890 by the Osceola Nursery Co., Osceola, Mo.

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[1] Ramsey, F. T., catalogue, 1908.

[2] The 17 seedlings raised at the Indian Head Experimental Farm, Saskatchewan, and listed in the Canada Experimental Farms Report, 1900, p. 426, are either *americana* or *nigra*.

[3] De Vries, Hugo. Plant Breeding, 1907, p. 213.

*__American Golden__, h. Introduced by James B. Wild & Bros., Sarcoxie, Mo., and said to have originated from seed planted near that place. Appears from the description to be *hortulana*.

Ames, 30, 34, am × tr. A seedling of De Soto pollinated by a Japanese variety, originated by J. L. Budd, Ames, Iowa. The foliage shows very little Japanese character.

Anderson, 30, am. Found wild beside the Turkey River, near Sioux Rapids, Iowa, by Mrs. Vincent Anderson.

Anderson (No. 2), 30, n. A seedling grown in Iowa.

Anderson's Early Red. See ANDERSON.

*__Anna__, am. A variety grown by Mr. Charles Gibb, of Montreal, Quebec, from wild stock secured in Wisconsin. Its origin as well as the description indicates *americana*.

*__Annual Bearer__, am. A seedling grown by Edson Gaylord, Nora Springs, Iowa, and said by E. S. Goff to be an *americana*.

*__Apple__, am. An Iowa seedling of Hawkeye, said by Hedrick [1] to be an *americana*, Patten No. 40.

Apple, 34, mu × tr. Originated by Luther Burbank, Santa Rosa, Cal., who states that Satsuma and probably Robinson are in its line of ancestry.

*__Apricot__, am. Listed as an *americana* by J. W. Kerr, Denton, Md.

*__Arctic.__[2] A native Manitoba variety grown by Thomas Frankland, Stonewall, Manitoba.

Arkansas, 14, 20, 30, 34, 37, mu. Originated in Arkansas and introduced by J. D. Morrow & Son.

Arkansas Lombard. See ARKANSAS.

*__Assiniboia.__ A native seedling grown at the Indian Head Experimental Farm, Saskatchewan.

*__Assiniboin.__ Mentioned by N. E. Hansen [2] as a pure native grown from pits secured in Manitoba. Perhaps the same as the preceding.

Atkins, 30, am. Found on the farm of James Beatty, near Atkins, Benton Co., Iowa, and introduced about 1894 under the name Beatty.

August, 14, n. Introduced by J. W. Kerr, Denton, Md.

August Red. See AUGUST.

Aurora, 14, h. Grown by Theodore Williams, Benson, Nebr., and introduced in 1898 under the name Moreman's Cherry by J. W. Kerr, Denton, Md., who later changed the name to Aurora.

Bailey, 39, am.

Baker. See STODDARD.

Baldwin, 36, am. Originated on the Baldwin farm, near Council Bluffs, Iowa.

Bales, 3, h.

*__"BAQ,"__ tr × am (?). A variety offered by S. W. Snyder, Center Point, Iowa, and said to be a combination of Burbank, Brittlewood, and Quackenboss. It is probably merely *triflora* × *americana*.

*__Baraboo__, am. Found growing wild near Baraboo, Wis., about 1860 and introduced in 1897 by William Toole, of Baraboo. It is said by E. S. Goff to be an *americana*, and its origin indicates that species.

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[1] Hedrick, U. P. The Plums of New York, 1911, p. 396.

[2] Hansen, N. E. Some New Fruits, circular of the South Dakota Agricultural Experiment Station, spring of 1908.

Barnsback, am. Originated at Vermilion, S. Dak., and said by E. S. Goff to be an *americana*.

Barnsbeck. See BARNSBACK.

Bartlett. See OREN.

Bassett, 14, 36, ma. Found wild near Hammonton, N. J., and introduced about 1872 by William F. Bassett, of that place.

*__Bastle__. An unclassified variety tested at the Texas station, but probably a native.

*__Bean__, am. Found wild by H. Knudson, Springfield, Minn., and sent to J. S. Harris, La Crescent, Minn., in 1889.

Beatty. See ATKINS.

Beaty, 14, an v × mu. Originated under cultivation at Luling, Caldwell Co., Tex., by Lee Beaty and introduced by him in 1877.

Beaty Choice. See BEATY.

Beaty's Choice. See BEATY.

Beauty. See BEATY.

*__Bedford__. A seedling raised at the Indian Head Experimental Farm, Saskatchewan.

*__Bell__. A variety grown in the Smyth orchard at Plainview, Tex.

Belle. See TEXAS BELLE.

Bell's October. See BELL.

Bender, 14, am. Reported [1] to have been grown near Chaska, Minn., by Paul Wolf.

Benson, 14, h. Originated by Theodore Williams, Benson, Nebr.

Benson Market, 14, am. An unclassified variety grown by J. W. Kerr, Denton, Md.

*__Berry Hill__, am. Originated [2] with H. A. Terry, Crescent, Iowa, and introduced by F. W. Meneray, Council Bluffs, Iowa.

Bertha, 12, an v × tr. A variety grown in Mr. Hunt's yard at Nursery, Tex., and said to be a Chickasaw crossed with Kelsey.

Best of All. See BESTOVALL.

Bestovall, 14, h mi. Originated by T. V. Munson, Denison, Tex., and said to be a seedling of Miner pollinated with Abundance. The foliage and flowers, however, show no *triflora* characters.

Beta, 14, ma. A selection from the wild made by E. W. Winsor in New Jersey.

*__Beta__ (No. 4), am. Originated by N. K. Fluke, Davenport, Iowa, apparently from seed of De Soto. Originally Betta,[3] but evidently an error for Beta.

*__Biconical__, tr × an v (?). Originated with A. L. Bruce in Texas and said to be Abundance crossed with a Chickasaw.

Bilona, 20, tr × me. Originated with H. A. Biles, Roanoke, Tex., and believed to be a seedling of Chabot crossed with the native "big tree plum."

Bingaman. See OREN.

*__Birchland__, am. A variety of Minnesota origin and said by Hedrick[4] to be an *americana*.

Bixby, 14, 30, 32, am. Found wild on the homestead of N. W. Bixby, Edgewood, Clayton Co., Iowa, in 1847, and introduced in 1880 by C. H. True, of the same place.

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[1] Hedrick, U. P. The Plums of New York, 1911, p. 401.
[2] Hedrick, U. P. Op. cit., p. 402.
[3] Transactions of the Iowa Horticultural Society, 1900, p. 86.
[4] Hedrick, U. P. Op. cit., p. 403.

*__Black African__, an v. A variety described as a Chickasaw and offered by F. W. Ramsey in 1898.

Black Beauty, 20, mu ×.

Blackhawk, 14, 32, am. Found wild in Blackhawk County, Iowa.

Blackman, 33, mu × *A. persica*. A seedling of Wild Goose, grown by Dr. Blackman, Nashville, Tenn., from seed obtained by Mrs. Charity Clark in Rutherford County, Tenn.

Blackman. See CHARITY CLARK.

Black Utah Hybrid. See UTAH.

Blanche. See NELLIE BLANCHE.

*__Bluemont__, an w. Originated at Manhattan, Kans., and said by F. A. Waugh to be the sand plum.

Bomberger, 30, am. A seedling of Harrison, grown by H. A. Terry, of Crescent, Iowa.

*__Bonner__, mu × tr. Originated in Lamar County, Tex., and said by B. L. Adams,[1] of the Bonham Nurseries, Bonham, Tex., to be a cross between Wild Goose and Abundance.

Bossland, 30, am. Originated by Theodore Williams, Benson, Nebr., in 1895 and said by the originator to be a combination of Miner, Quackenboss, and Wayland. The material seen is pure *americana*.

Bouncer, 30, am. A seedling of purple Yosemite, originated at the Central Experimental Farm, Ottawa, Canada.

Brackett, 14, 30, am. A seedling of Harrison, grown by H. A. Terry, Crescent, Iowa.

*__Brainerd__, am. Found wild on the grounds of Mr. Brainerd in Ramsey County, Minn., by P. A. Jewell. Said by L. H. Bailey to be an *americana*.

Brainerd's Best. See BRAINERD.

*__Brandon Ruby__, n. Said by W. T. Macoun to be a *nigra* variety.

*__Breck__, tr × an v. Originated in the orchard of Joseph Breck, in Texas, and said by Mr. Ramsey to be a hybrid of a Japanese with a Chickasaw.

Brittlewood, 14, 32, am 1. Grown by Theodore Williams, Benson, Nebr., and said to be seed of Harrison pollinated by Quaker.

Brittlewood (No. 1). See BRITTLEWOOD.

Brittlewood (No. 2). See UNITED STATES.

Brittlewood (No. 3), 14, am 1. Grown by Theodore Williams, Benson, Nebr.

Brogden's Prolific, 7, h.

Brooklyn, 14, am. A seedling of Harrison, grown by H. A. Terry, Crescent, Iowa.

Bruning, 30, am. A seedling grown in Iowa.

Bruning (No. 2), 30, am. A seedling grown in Iowa.

Brunswick, 24, mu. Originated in Missouri and introduced by the Lovett Nursery Co.

Bryan, 14, 30, am. Originated with H. A. Terry, Crescent, Iowa.

*__Budd__, am. Originated by H. A. Terry, Crescent, Iowa, and said by F. A. Waugh to be an *americana*.

Buffalo Bill, 20, me. A selection made from the wild in Texas.

[1] Bonham Nurseries, catalogue, 1904–5, p. 10.

Bulah, 30, h mi. Originated under cultivation with J. F. Wagner, Bennett, Cedar Co., Iowa, in 1894 from seed of Miner pollinated by a wild plum. The material appears to be pure *mineri*.

Bulah (No. 4). See BULAH.

Burbank × Redick, tr × am. Originated by Theodore Williams, Benson, Nebr.

Burbank's Combination. See COMBINATION.

*__Burdick__, am. Offered by Youngers & Co., Geneva, Nebr., and apparently an *americana*.

*__Burford__, tr × mu. A seedling of Burbank crossed with Clifford, grown by T. V. Munson, Denison, Tex.

Bursoto, 14, am × tr. Originated by Theodore Williams, Benson, Nebr. Supposed to be a hybrid of Burbank with De Soto, but it shows very little of the *triflora* character.

Burwood. See EMERALD.

*__Butler__, mu. A variety offered by W. H. Halloway, Butler, Bates Co., Mo., and said to be a seedling of Wild Goose.

Caddo Chief, 14, an. Found wild in Caddo Parish, La., and introduced by G. W. Stoner, Shreveport, La.

California, 14, am.

California Seedling. See CALIFORNIA.

*__Campbell__, am (?). Scions taken from an old tree growing on a clump of rocks in the vicinity of Abingdon, Va., and named for the family near whose place it was found. Said by Thomas Mehan to resemble the common American red plum.

*__Canadian Apricot__, n. Said to be the common wild plum of Canada.[1]

*__Canary__, am. A variety received by J. S. Harris in 1889 from H. Knudson, Springfield, Minn.[2]

Canawa. See KANAWHA.

Caneford, 37, am. A specimen under this name was received from the Washington Agricultural Experiment Station.

Captain. See CUMBERLAND.

Captain Bacon, 27, am. A seedling of Weaver, grown by H. A. Terry, Crescent, Iowa.[3]

*__Captain Watrous__, am. A seedling of Harrison, grown by H. A. Terry, Crescent, Iowa.

*__Caro__, am 1. A seedling of Wolf, originated at the Central Experimental Farm, Ottawa, Canada.

*__Caroline__, am. Originated with C. W. H. Heideman, New Ulm, Minn. Apparently an *americana*.

*__Carpenter__. A seedling variety from Vermilion, S. Dak.

Carstesen, 9, n. A *nigra* seedling originated by H. P. Carstesen, Billings Bridge, near Ottawa, Ontario.

Carver, 14, h. Introduced by Charles Luedloff, Cologne, Minn.

*__Centennial__. From seed of plums brought by a Mr. Drake from his farm in Le Sueur, Minn., to Iowa, in the fall of 1876, and grown by George W. Oberholtzer, Sioux City, Iowa.

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[1] Hedrick, U. P. The Plums of New York, 1911, p. 414.

[2] Harris, J. S. Minnesota Horticultural Society Report, 1890, p. 128.

[3] Hedrick, U. P. Op. cit., p. 415.

*__Champa__, b. A seedling of Sioux (*Prunus besseyi*), grown by N. E. Hansen, Brookings, S. Dak.[1]

Champion, 14, 30, 37, am. A seedling of Hawkeye, grown by H. A. Terry, Crescent, Iowa.

Charity Clark, mu. The original Blackman, renamed to avoid confusion with the plum-peach hybrid of that name. A seedling of Wild Goose, originated about 1862 with Dr. Blackman, of Nashville, Tenn., from seeds obtained by Mrs. Charity Clark from an orchard in Rutherford County, Tenn.

Charles Downing. See DOWNING.

*__Charmer__. A seedling grown at the Indian Head Experimental Farm, Saskatchewan.

Cheney, 14, 30, 32, 34, 36, 37, n. Found by E. Markle, of La Crosse, in Vernon County, Wis., and introduced about 1887.

*__Cheresoto__, b × am. *Prunus besseyi* crossed with De Soto, according to N. E. Hansen, the originator.

Cherokee, 14, am. Said to have been found wild in Kansas.

*__Cherry__, n. Found wild in Morman ravine, near Chaseburg, Vernon Co., Wis., by E. Markle, about 1870.

Chickasaw Chief. See MINER.

*__Chicrigland__, r × an × A. texana (*P. glandulosa*). Originated by T. V. Munson, Denison, Tex., from seed of a plum grown by F. T. Ramsey, Lampasas County, Tex. Said to be a combination of Chickasaw, *rivularis*, and *glandulosa*, but there is little doubt that the so-called *rivularis* was *reverchonii*.

*__Chinook__. A seedling grown at the Indian Head Experimental Farm, Saskatchewan.

*__Chippewa__, am. A variety from Chippewa Falls, Wis., and said by L. H. Bailey to be *americana*.

Chippeway. See CHIPPEWA.

Choptank, 14, mu × h. A seedling of Wild Goose, originated by J. W. Kerr, Denton, Md., but the material indicates admixture with *hortulana*.

*__Christie__, am. A variety taken from a thicket of wild plums near Villisca, Iowa, by W. Christie, and said by Craig and Vernon to be *americana*.

*__Cikana__, b × (mu × tr). A hybrid of *prunus besseyi* pollinated with Gold (Golden), according to the originator, N. E. Hansen.

*__Cistena__, b × c a. Sand cherry crossed with purple-leaved Persian plum, according to the originator, N. E. Hansen.

City, 30, am. Originated under cultivation with H. Knudson, Springfield, Minn., from seed of a wild plum found near that place. Introduced in 1889 or 1890.

*__Clara__, mu. A seedling of Wild Goose, grown by G. Onderdonk, Nursery, Tex.

*__Clarendon__, an w. A variety obtained from northern Texas by F. T. Ramsey and said by F. A. Waugh to be the sand plum.

Clark, 14, an. Said to have been found wild in Anne Arundel County, Md.

*__Clark's Everbearing__. A variety grown by F. K. McGinnis, Terrell, Tex.

*__Clemon's Seedling__. A native variety found growing wild on Mr. Clemon's farm, Davenport, Iowa.[2]

Cleveland, 14, mu. A seedling of Wild Goose, grown by H. A. Terry, Crescent, Iowa.

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[1] Hansen, N. E. Some New Fruits, circular of the South Dakota Agricultural Experiment Station, spring of 1912.

[2] Fluke, N. K. Transactions of the Iowa Horticultural Society, 1882, p. 233.

Clifford, 14, 20, mu. Originated by Mrs. E. C. Clifford, Denison, Tex., and said to be a seedling of Wild Goose.

Clingstone Wolf. See Wolf Clingstone.

Clinton, 14, 29, 37, h mi.

Cluck, 14, an v. Originated with George Cluck, near Austin, Tex., and introduced in 1896 by F. T. Ramsey, of Austin.

Coinage, 30, am. Originated with H. A. Terry, Crescent, Iowa, and said to be a seedling of Gold Coin.[1]

***Coleman Late.** A variety offered by A. K. Clingman, Homer, La., in 1889.

Coletta, 14, an v. Originated in southern Texas by G. Onderdonk, who introduced it in 1874.

Collman, 30, am. Originated with H. A. Terry, Crescent, Iowa, and said to be a seedling of Harrison.

Colman. See Collman.

Colonel Bryan. See Bryan.

Colonel Wilder. See Wilder.

Colorado. See Colorado Queen.

Colorado Queen, 14, am. Introduced by J. W. Kerr, Denton, Md.

Columbia. See Cumberland.

***Columbia Wonder.** Offered in 1894 by the Cumberland Nurseries, Tennessee.

Combination, 20, tr ×. Originated by Luther Burbank, Santa Rosa, Cal., and evidently a hybrid of *triflora* with some native.

Combination (Williams), 14, 30, am × tr. Originated with Theodore Williams, Benson, Nebr.

Comfort, 14, 32, am. Introduced by J. Wragg & Sons, Waukee, Iowa, about 1879.

Compass, 32, h mi × p or b. Originated by H. Knudson, who states that it is the sand cherry pollinated with Miner.

Compass Cherry. See Compass.

Comptine, 14, 37, am. A variety originated at Knoxville, Iowa.

Consul, am l. A seedling of Wolf, originated at the Central Experimental Farm, Ottawa, Canada.

Cook. See Cook Choice.

Cook Choice, 14, h × am. An accidental seedling, originated with H. A. Terry, Crescent, Iowa.

Cook's Choice. See Cook Choice.

Cook's Favorite. See Cook Choice.

Cooper, 14, am × mu. Grown by Theodore Williams, Benson, Nebr., from seed of Forest Garden pollinated by Pottawattamie.

Cotterell. See Cottrell.

Cottrell, 14, 30, 37, am. A seedling raised by R. T. Cottrell, of Dover, Olmsted Co., Minn., and introduced in 1888 by O. M. Lord, of Minnesota City.

***Couler**, am. A variety from William Couler, Chickasaw County, Iowa, and apparently an *americana*.

***Crable**, am. An Iowa variety, thought by F. A. Waugh to be an *americana*.

Craig, 30, am. A seedling of Harrison, grown by H. A. Terry, Crescent, Iowa.

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[1] Hedrick, U. P. The Plums of New York, 1911, p. 421.

Crescent, 30, 37, h mi × am (?). Originated with H. A. Terry, Crescent, Iowa, and said to be a seedling of Miner. The foliage indicates admixture with *americana*.

Crescent City. See CRESCENT.

Crimson, 14, 30, n. Introduced by H. Knudson, Springfield, Minn.

Crimson Beauty, 14, h.

***Cuba.** A variety offered by the Mount Hope Nursery, Washington, La., and classed with the natives, although said to have come from Cuba.

***Culberson**, h. A variety from A. L. Bruce, Basin Springs, Tex., and said to be a cross of Miner and Crimson Beauty.

Cumberland, 14, h. Originated near Augusta, Ga., from seeds collected on the Cumberland Mountains in 1864.

***Curry**, mu. A variety grown by S. L. Curry, Weldon, Iowa, which apparently belongs to the Wild Goose group.

***Cyclone**, am. A seedling of Harrison, grown by H. A. Terry, Crescent, Iowa.

Dahlgreen, 14, am. Introduced by Charles Luedloff, Cologne, Minn.

***Daisy**, an × tr. Originated by J. S. Breece, Fayetteville, N. C., and said by F. A. Waugh to be a hybrid of *angustifolia* with *triflora*.

***Dakota**, am. Said to be an *americana* by J. W. Kerr, Denton, Md.

***Daniel Weeping.** Originated with Dr. Daniel in Louisiana, and according to F. A. Waugh has the aspect of a hybrid.

Davenport, 30, am. A seedling of De Soto, grown by N. K. Fluke, Davenport, Iowa.

Davis, 14, mu. A seedling of Wild Goose, grown in 1885 by H. A. Terry, Crescent, Iowa.

***Dawson.** A variety grown at one time on the banks of the Ohio and probably a native.

***Dawson City.** A seedling raised at the Indian Head Experimental Farm, Saskatchewan.

Dayton, 19, h × tr. A variety offered by A. M. Ragland, Pilot Point, Tex.

***Decker**, h mi. A seedling raised about 1885 by H. C. Decker, Dresbach, Minn., and said by E. S. Goff to belong to the Miner group.

Decker's Late Seedling. See DECKER.

Deep Creek, 14, 28, am. A Kansas wild variety, introduced by Abner Allen.

Dennis, 14, 30, am. A seedling of Hawkeye, originated by H. A. Terry, Crescent, Iowa.

***Dennis' Seedling** (No. 13), h mi. A variety grown at the Iowa Agricultural Experiment Station, and said to belong to the Miner group.[1]

***Denton**, an v. A variety introduced by J. W. Kerr, Denton, Md.[1]

Des Moines, 14, am. A variety of Iowa origin.

De Soto, 14, 30, 32, 33, 34, 37, am. First discovered in a ravine near the site of the present village of De Soto, Wis., and disseminated about 1864 by Elisha Hale, Lansing, Iowa.

De Soto × Oregon No. 3. See AMES.

***Dewey**, am. A seedling of De Soto, grown by H. A. Terry, Crescent, Iowa.

***Diamond**, am. Originated from wild seeds collected about 1880 by John A. Hogg, Buffalo County, Nebr.

Diana, 36, am. A seedling of Hawkeye, grown by H. A. Terry, Crescent, Iowa.

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[1] Hedrick, U. P. The Plums of New York, 1911, p. 431.

Doctor Dennis. See DENNIS.

*__Don__, am 1. A seedling of Wolf, originated at the Central Experimental Farm, Ottawa, Canada.

*__Dora__, tr × mu. Originated with A. L. Bruce, in Texas, and said to be a cross between Abundance and Wild Goose.

*__Doris__, c × an v (?). Originated by Luther Burbank, Santa Rosa, Cal., who believed it a hybrid between a Myrobalan and a Japanese variety, but said by F. A. Waugh to be apparently a hybrid between a Myrobalan and a Chickasaw.

Dorothy, 5, am.

Dorsett, 27, mu. A chance seedling, originated with H. A. Terry, Crescent, Iowa, and introduced by F. W. Meneray, Council Bluffs, Iowa.

Douglas, 27, am. A seedling of Harrison, grown by H. A. Terry, Crescent, Iowa, and introduced by F. W. Meneray, Council Bluffs, Iowa.

Downing, 14, 30, 33, 34, mu. A seedling of Wild Goose, originated in 1882 by H. A. Terry, Crescent, Iowa.

Drouth King, 14, mu.

*__Duarte__, (mu × tr) × (tr × s). A variety offered in 1911 by the Comal Springs Nursery, New Braunfels, Tex., and said to be from seed of America pollinated by Climax.

*__Duke__, mu × am (?). Originated by Theodore Williams, Benson, Nebr., who supposed it to be Wild Goose crossed with Duke Cherry, but said by F. A. Waugh to be a hybrid of *munsoniana* with *americana*.

Dunlap, 14, 20, 30, 37, h. A Nebraska seedling, introduced by J. P. Dunlap, of the same State.

Dunlap (No. 1), 14, am. A variety originated by J. P. Dunlap, of Nebraska.

Dunlap (No. 2). See DUNLAP.

*__Dunlop Nut__, am.[1] A variety grown at the Central Experimental Farm, Ottawa, Canada, and said to be an *americana*.

Dwarf Rocky Mountain Cherry. See ROCKY MOUNTAIN CHERRY.

Eagle, 2, 14, 20, 34, an v × mu. A variety of Texas origin.

*__Early Honey__, an v. Originated in Grayson County, Tex., and said by L. H. Bailey to be evidently a Chickasaw.

*__Early Minnesota__, am. Found wild by Joseph Wood, Windom, Minn., and said by N. E. Hansen to be an *americana*.

Early Red, 14, an. Originated at the Mission Valley Nursery, Victoria County, Tex., by G. Onderdonk, and disseminated in 1879.

Early Six Weeks. See SIX WEEKS.

*__Early Sweet__, an v. A variety offered by F. T. Ramsey in 1907 and classified as a Chickasaw.

Early Vermont, 30, am. Originated with J. Erwin Lord, Pompanoosuc, Vt.

Eaton, 22, 37, am. A variety grown by George H. Spear, Greeley, Colo., and also by the Washington Agricultural Experiment Station.

*__Echo__, an v (?). A variety offered by the Mount Hope Nursery, Washington, La., and said to ripen with Caddo Chief.

Eddie, 14, am. Originated with Theodore Williams, Benson, Nebr.

*__Edith__, am. A seedling of Iowa Beauty, grown by E. L. Hayden, Oakville, Iowa, and said by Craig and Vernon to be an *americana*.

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[2] Hedrick, U. P. The Plums of New York, 1911, p. 437.

Edith (Terry). See JULIA.

*Eggles, tr × h. Originated with A. L. Bruce, in Texas, and said to be a hybrid of Abundance with Crimson Beauty.

Eldora, 14, h. A variety received previous to 1894 by H. A. Terry, Crescent, Iowa, from Judge Samuel Miller, of Missouri.

Eldorado, 30, am. Originated with H. A. Terry, Crescent, Iowa, and introduced in 1899.

*Eldridge,[1] am. A variety of Wisconsin origin, said by Hedrick to be an *americana*.

*Ellis, mu × h. A variety introduced by T. L. Ellis in northern Texas; believed to be a cross between the Wild Goose and Golden Beauty.

El Paso. See BEATY.

Emerald, 30, tr × am. Originated by Theodore Williams, Benson, Nebr., by crossing Burbank with Brittlewood.

*Emerson,[1] am. Originated near Dubuque, Iowa, and said by Hedrick to be an *americana*.

Emerson (Bruce), 14, an v. A variety found wild in northern Texas and introduced by A. L. Bruce.

Emerson's Early. See EMERSON (Bruce).

Emerson Yellow, 14, an v × mu. A seedling of Emerson (Bruce), originated in Texas.

Emma, 30, am. A variety grown by H. A. Terry, Crescent, Iowa.

*Enopa, b × tr. Sand cherry crossed with Sultan plum, according to the originator, N. E. Hansen, Brookings, S. Dak.

Erby September. See IRBY.

*Estella, mu (?). A native seedling offered by the Sunny Slope Nursery, Hannibal, Mo., which, from the description, appears to belong to the Wild Goose group.

Esther, 14, h mi. A seedling of Miner, grown by H. A. Terry, Crescent, Iowa.

*Etopa, b × tr. A hybrid of the sand cherry and Sultan plum, according to the originator, N. E. Hansen, Brookings, S. Dak.

Etta, 10, 14, am. A variety grown by H. A. Terry, Crescent, Iowa.

*Eureka, n. Said to be a seedling of Cheney, grown by Theodore Williams, Benson, Nebr., in 1896.

*Eureka, mu. A name given one of the Wild Goose seedlings disseminated soon after the introduction of that variety, according to D. L. Adair.

*Eva. A native Manitoba plum, grown by Thomas Frankland, Stonewall, Manitoba.

*Everbearing, an v (?). A variety offered by the Paris Nursery, Paris, Tex., and the Comal Springs Nursery, New Braunfels, Tex., and classed with the Chickasaws.

Excelsior, 14, 16, 20, tr × an v or mu. Originated in 1887 by G. L. Taber, Glen Saint Mary, Fla., from seed of Kelsey supposed to have been pollinated by Wild Goose.

*Eyami, b × tr. The sand cherry crossed with the Sultan plum, according to the originator, N. E. Hansen, Brookings, S. Dak. Introduced in 1908.

*Ezaptan, b × tr. The sand cherry crossed with the Sultan plum, according to the originator, N. E. Hansen, Brookings, S. Dak. Introduced in 1911.

Fairchild, 30, am. Grown in 1894 by J. H. Fairchild in Linn County, Iowa, from seed of De Soto supposed to have been pollinated by a Nebraska wild plum.

[1] Hedrick, U. P. The Plums of New York, 1911, p. 442.

Fancy, 30, mu. Originated with John Brown, Oakville, Louisa County, Iowa, in 1885, being a sprout from the stock of a Wild Goose tree.

***Fanning**, mu. A chance seedling found in the yard of Mr. Fanning, Rockdale, Tex., and introduced by J. N. Shell, of Georgetown, Tex. Said by F. T. Ramsey to belong to the Wild Goose group.

Fawn, 14, an v. A variety first grown by David Miller, Camp Hill, Cumberland Co., Pa.

***Fin de Siecle.** A seedling raised at the Indian Head Experimental Farm, Saskatchewan.

First, 14, tr ×. Originated with Luther Burbank, who says it is a second-generation combination cross of Hawkeye, Hammer, Milton, Wyant, Wayland, and Burbank.

***First Sweet.** A seedling raised at the Indian Head Experimental Farm, Saskatchewan.

Fitzroy, 30, am. A seedling of Rollingstone, grown at the Central Experimental Farm, Ottawa, Canada.

***Flora Plena**,[1] am. Found by J. W. Kerr in the yard of a friend in York County, Pa., having been brought there from Iowa.

***Florida Queen**, tr ×. Originated by Henry Reed, in Baker County, Fla., and supposed to be a seedling of Kelsey crossed with a native Florida species.[2]

Forest Garden, 14, 36, am. Originated on Cedar River, near Cedar Rapids, Iowa, and introduced about 1862 by H. C. Raymond, Council Bluffs, Iowa.

Forest Rose, 14, 29, 34, 37, h mi. Believed by J. L. Budd to have originated in Missouri with Scott & Co.

***Forest Rose Improved**, h mi.

Forewattamie, 14, 30, am × mu. Originated with Theodore Williams, Benson, Nebr. and said to be a hybrid of Forest Garden with Pottawattamie.

Fourth of July. See MARBLE.

***Franklin**, tr × an v. Originated with A. L. Bruce, in Texas, who described it as a hybrid of Abundance with an unknown variety. Believed by Waugh to be a hybrid of Abundance with a Chickasaw.

Freeman, 14, mu. Grown by H. A. Terry, Crescent, Iowa, in 1885, from seed of Wild Goose.

Freeman's Favorite. See FREEMAN.

Free Silver. See TERRY.

***Freestone**, am. A seedling of Harrison, grown by H. A. Terry, Crescent, Iowa.

***Freestone Goose**, mu. Originated by Theodore Williams, Benson, Nebr., and introduced in 1910 by Stark Bros., Louisiana, Mo., who describe it as an improved Wild Goose.

***Fuller**. A variety grown by B. A. Mathews, Knoxville, Iowa, and listed by E. S. Goff as a native.

Fuller's Egg. See FULLER.

Funk, 20, tr × an v. An accidental seedling raised by J. M. Funk, Grayson County, Tex., and said to be a seedling of Abundance crossed with a Chickasaw.

Funk's Early. See FUNK.

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[1] Hedrick, U. P. The Plums of New York, 1911, p. 446.

[2] Turkey Creek Nurseries, catalogue, 1907-8, p. 11.

Gale, h mi (?). A variety sent to the Wisconsin Agricultural Experiment Station in 1891 by J. Gale & Son, Waukesha, Wis. It is said by E. S. Goff to be an *americana*, but since he describes the leaves as being glandular and obtusely serrate, it can not be that species. Specimens from J. W. Kerr under the name Gales appear to be *hortulana mineri*, although it may be a bybrid with *americana*, the influence of the latter species appearing mainly in the fruit.

Galena, 14, am. Introduced by Charles Luedloff, Cologne, Minn.

Gales. See GALE.

Gale Seedling. See GALE.

Gale's No. 3. See GALE.

***Gamma No. 6**,[1] am (?). Originated with N. K. Fluke, Davenport, Iowa, apparently from seed of De Soto.

Garber, 30, h mi. A variety offered in 1902 by S. W. Snyder, Center Point, Iowa, who says it is a seedling of Miner.

***Garden King**, am. Found wild in 1853 and cultivated in 1861 by Judge Elias Topliff, De Soto, Wis., from whom it was obtained by A. R. Prescott, Postville, Allamakee Co., Iowa, and introduced in 1896.

Garfield, 14, h. Reported to have been found wild in Ohio and introduced in 1887 by Leo Welz, Wilmington, Ohio.

Gates, am. Originated at Owatonna, Minn., and described as an *americana* by E. S. Goff.

***Gaviota**, am × tr (?). A variety originated with Luther Burbank about 1900 and described as being a hybrid of *triflora* and *americana*, with probably half a dozen others combined with it.

Gaylord, 14, am. Found wild about 1854 by David Hardman, Nora Springs, Iowa, and introduced by Edson Gaylord, of the same place.

***Gaylord Gold**, am. Found wild by John Henry, Nora Springs, Iowa, about 1880, and disseminated by Edson Gaylord. Reported by Craig and Vernon to be an *americana*.

Gaylord Quality. See QUALITY.

Gem, 27, am. A seedling of Lottie, grown by H. A. Terry, Crescent, Iowa, and introduced by F. W. Meneray, Council Bluffs, Iowa.

General Jackson. See MINER.

***Georgia**, tr × mu or an. Originated with J. L. Normand, Marksville, La., and from the description and figure given by L. H. Bailey it appears to be a hybrid of *triflora* with either *munsoniana* or *angustifolia*.

German Prune Seedling. See MANKATO.

Gillett. See MINER.

Gloria, 36, am l. Seedling of Wolf.

***Glow**. Originated by Luther Burbank, Santa Rosa, Cal., who says it is a combination of *maritima*, *americana*, *subcordata*, and *nigra*.

***Goff**, am. A seedling of Hawkeye, grown by H. A. Terry and introduced by F. W. Meneray, Council Bluffs, Iowa.

Gold (not the Gold of Stark Bros.), 14, 31, 37, am. Introduced by H. A. Terry, Crescent, Iowa, in 1898.

Gold (Stark Bros.) See GOLDEN.

***Gold Coin**, am. A variety mentioned by H. A. Terry as the parent of Coinage.

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[1] Transactions of the Iowa Horticultural Society, 1900, p. 86.

*__Gold Colored__, am. A variety from Edson Gaylord, Nora Springs, Iowa, said by E. S. Goff to be an *americana*.

Golden, 34, mu × tr. Originated with Luther Burbank, who says it is a seedling of Robinson crossed with Sweet Botan [Abundance]. It was renamed Gold by Stark Bros.

Golden (*americana* var.). See GOLD.

Golden Beauty, 14, 20, 30, 34, h. Introduced in 1874 by Gilbert Onderdonk, of Nursery, Tex., who says it was obtained in the region of Fort Belknap, Tex., by a German who brought it to Gonzales County at the close of the Civil War.

*__Golden Drop__, an v. A variety listed as a Chickasaw in 1907 by F. T. Ramsey, Austin, Tex.

Golden Mammoth, 33, am. Secured many years ago by the Missouri Agricultural Experiment Station from Mr. N. F. Murray, of Oregon, Holt Co., Mo. Mr. Murray brought it from his old home near Wheeling, W. Va., where it was a local variety.

Golden Queen, 14, 30, am. Originated with H. A. Terry, Crescent, Iowa.

Gonzales, 14, 20, an v × tr. Originated in Gonzales, Tex., about 1894.

Goosedye, 14, mu × *P. cerasus*. Grown by Theodore Williams, Benson, Nebr., and said to be a hybrid of Wild Goose with Dyehouse Cherry.

Goose-O, 14, mu × tr. Originated by Theodore Williams, Benson, Nebr., and supposed to be a hybrid of Wild Goose and Ogon.

*__Gorman__. Mentioned by S. W. Snyder, Center Point, Iowa, as belonging to either the Chickasaw or Wayland group.

Govalle, 20, an v × tr. Originated by Joseph Breck, in Texas, and introduced by F. T. Ramsey, Austin, Tex.

*__Gowa__, mu × h. A supposed hybrid of Wild Goose and Wayland.

Grace, am. Originated with W. R. Grace, Garden City, Kans.

Grayson, 14, 37, mu × me. Originated with A. L. Bruce, in Texas, as a seedling of Wild Goose, apparently pollinated with the native *mexicana*.

Guilford, 30, am.

*__Guilford__ (No. 2), h mi. A seedling of Miner, grown by H. T. Thompson, Marengo, Ill.

*__Guinea Egg__, am. Found wild about 1857 by Frederick Albright, near Bangor, Marshall Co., Iowa, and reported as an *americana* by Craig and Vernon.

Haag, 14, am. Purchased from a nursery at Minneapolis and introduced by Jacob S. Haag, Hospers, Sioux Co., Iowa.

*__Halcyon__, tr × an. Originated with J. S. Breece, Fayetteville, N. C., and reported by F. A. Waugh as a hybrid of *triflora* with *angustifolia*.

Hammer, 14, 34, 36, h mi × am. Originated about 1888 with H. A. Terry, Crescent, Iowa, who says it is a seedling of Miner pollinated by some *americana*.

*__Hanska__, am × s. A seedling of *americana* crossed with *simonii*, according to the originator, N. E. Hansen, Brookings, S. Dak.

Hanson, 14, n.

*__Happiness__, tr × mu. A seedling found by Joseph Breck about 1899 and introduced by F. T. Ramsey, Austin, Tex., who describes it as a hybrid of Japanese and Wild Goose.

*__Harper__,[1] mu (?). Said to have originated about 1870.

Harper's. See HARPER.

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[1] Hedrick, U. P. The Plums of New York, 1911, p. 458.

***Harris**,[1] h mi. A variety grown at one time by D. Wilmot, Scott, Ill., and from the description it probably belongs to the Miner group.

Harrison, 14, am. Reported by J. S. Harris to have originated at Minneapolis, Minn.

***Harrison Large Red**, am. A native variety, mentioned by J. S. Stickney, Wauwatosa, Wis. It appears from the description to be an *americana*.

Harrison's Peach. See HARRISON.

Hart, 32, am. A sprout taken from a tree bought for De Soto by H. Hart, Sioux County, Iowa.

Hart's De Soto. See HART.

Hartwick, 14, am.

***Harvest**, am. A variety received by J. S. Harris in 1889 from H. Knudson, Springfield, Minn., and apparently an *americana*.

***Hattie**, c × an v (?). From the description given of this variety it appears to be of the same type as Marianna.

***Hattie Porter**, an v (?). A variety offered in 1890 by the Milford Nurseries, Milford, Del., and described as a Chickasaw.

Hawkeye, 14, 32, 34, 36, 37, am. A seedling of Quaker, grown by H. A. Terry, Crescent, Iowa, and introduced in 1883.

Heaton, 14, 37, am. A variety received about 1894 by J. W. Kerr, Denton, Md., from H. A. Terry, Crescent, Iowa.

***Heep**, an v (?). A variety found growing in the orchard of Mr. Heep by F. T. Ramsey, Austin, Tex., who introduced it in 1897 or 1898. Classed with the Chickasaws by J. W. Kerr.

Heideman Black, 14, b.

Heideman (No. 88), 14, am ×.

Heideman Red, 14, b.

Heideman Yellow, 14, b.

***Heming**, an v (?). Offered by the Clingman Nurseries, Homer, La., who say it is of Florida origin and one of the best of the Chickasaws.

***Hendrick**, an v (?). A variety classified as a Chickasaw by J. S. Newman.

Hendrick's. See HENDRICK.

Hiawatha, 14, am. A variety disseminated by C. W. H. Heideman, New Ulm, Minn.

***Hilda** (No. 5), h mi. Originated under cultivation with J. F. Wagner, Bennett, Iowa, in 1894, from seed of Miner pollinated by the wild plum. It is classified as *hortulana* by Craig and Vernon.

***Hillside**, am. A variety received by J. S. Harris in 1889, from H. Knudson, Springfield, Minn., who introduced it from the wild. It is apparently an *americana*.

Hilltop, 14, 37, am.

***Hilman**,[2] am.

Hinckley. See MINER.

***Hinckley**, am. A seedling of Harrison, grown by H. A. Terry, Crescent, Iowa, and introduced by F. W. Meneray, Council Bluffs, Iowa.

***Hoffman**, mu. A wild variety from southwestern Missouri, which appears from the description to belong to the Wild Goose group.

Hoffman Seedling. See ROSELLE.

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[1] Hedrick, U. P. The Plums of New York, 1911, p. 459. [2] Hedrick, U. P. Op. cit., p. 462.

Hogg's (No. 2). See Marianna.

Holister, 14, mu. Originated in Cedar County, Iowa, by a Mr. Holister.

Holland, 14, tr × an v. A variety grown by D. H. Watson, Brenham, Tex., and said to be a seedling of Kelsey pollinated with Lone Star.

Holt, 14, am. Grown by J. B. Holt, Rutland, Ohio.

*__Homestead__, am. Originated with H. Knudson, Springfield, Minn., about 1889. From the description it appears to be an *americana*.

Honey, 14, am.

Honey Drop. See GOLDEN BEAUTY.

Honey Grove. See SANDERS.

*__Hoosier__,[1] h. Originated in Greene County and introduced by Wild Bros., Sarcoxie, Mo.

*__Hope__. A seedling grown by G. Onderdonk[2] and offered in 1901.

*__Hoskins__,[3] am. A variety originated by Mr. Hoskins, Pleasant Plain, Jefferson Co., Iowa, and introduced by J. Wragg & Son, Waukee, Iowa. Said by J. W. Kerr to be an *americana*.

*__Houston County__. An unclassified variety mentioned by L. H. Bailey.

*__Howe__, tr ×. A seedling of Kelsey pollinated by some native originating in Mrs. Stumpe's yard in Putnam County, Fla., and introduced by Griffing Bros.

Hughes, 14, 37, mu. Originated in northeastern Mississippi.

Hughes Late. See TECUMSEH.

Hunt, 30, mu × am. Grown by Henry Hunt about 1880 from seed of Wild Goose supposed to have been pollinated by a wild plum of pure *americana* type, and introduced in 1898 by M. J. Graham, Adel, Iowa.

Hunt De Soto, 14, 37, am. An Iowa variety, introduced by J. L. Budd, of the Iowa Agricultural Experiment Station.

Hunt's De Soto. See HUNT DE SOTO.

*__Huya__, am. A variety grown by N. E. Hansen,[4] Brookings, S. Dak., who says it is an *americana*.

Ida, 14, am. Originated by D. B. Wier in Illinois.

Idal. See IDALL.

Idall, 14, h mi × am. Said by the originator, D. B. Wier, of Illinois, to be a cross between Wild Goose and Miner. The foliage indicates that it may be a hybrid of Miner with an *americana*, the latter species being particularly evident.

Idol. See IDALL.

Illinois Ironclad. See IRONCLAD.

Illinois Plum. See LANGSDON.

*__Imperial__, am. A variety received at the Iowa Agricultural Experiment Station from C. B. Gingrich, Laporte City, Iowa, in 1899. Said by J. W. Kerr to be an *americana*.

Improved Dwarf Rocky Mountain Cherry. See ROCKY MOUNTAIN CHERRY.

Improved Rocky Mountain Cherry. See ROCKY MOUNTAIN CHERRY.

Indiana, 14, 29, h mi. Reported to have been found wild in Indiana and introduced by Dr. J. Cramer.

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[1] Hedrick, U. P. The Plums of New York, 1911, p. 463.

[2] Mission Valley Nurseries, catalogue, 1901–2, p. 13.

[3] Hedrick, U. P. Op. cit., p. 464.

[4] Hansen, N. E. Some New Fruits, circular of the South Dakota Agricultural Experiment Station, spring of 1908.

Indiana Red. See INDIANA.

Indian Chief, 14, 20, mu. Origin uncertain.

***Ingels.** A variety listed as a native by the Home Nursery, Lafayette, Ill.

***Inkpa,** am × s. A hybrid of the wild plum crossed with *simonii*, according to the originator, N. E. Hansen, Brookings, S. Dak. Introduced in 1909.

***Iola.** A variety grown by D. B. Wier in Illinois.

Iona, 14, 37, h mi. Said by D. B. Wier, the originator, to be pure *americana*, the seed coming from a wild bush in southwestern Wisconsin. The variety now grown under this name is *hortulana mineri*.

Iowa, 14, am. A variety from Allamakee County, Iowa.

Iowa Beauty, 14, am. A wild variety taken from the woods, about 1859, by Hugo Beyer, New London, Iowa.

Irby, 20, h. Found by Dan Irby, of Texas, growing on the grounds of an old Indian settlement in Cherokee County, Tex.

Irby September. See IRBY.

Irene, 14, 37, h mi. Originated with D. B. Wier in Illinois.

Iris, 14, 37, h mi. Originated and introduced by D. B. Wier in Illinois.

Ironclad, 14, 37, am. A wild Illinois variety, introduced by Stark Bros., Louisiana, Mo., in 1890.

***Iroquois,** h mi. From Charles Luedloff, Cologne, Minn. Referred to the Miner group by W. T. Macoun.

Isaac, 14, am. A wild variety from near Lincoln, Nebr., brought to notice by M. S. Hubbell.

Isabel. See MINER.

Isabella, 14, am. A variety grown by H. A. Terry, Crescent, Iowa.

Itasca, 14, 32, 37, n. A variety from Minnesota, introduced by P. M. Gideon, Excelsior, Minn., and by W. F. Heikes, Huntsville, Ala.

Itaska. See ITASCA.

***Ithaca.** A variety from Peter M. Gideon, Excelsior, Minn.

Ivason, 14, am. Originated in Iowa and brought to attention by M. S. Hubbell, Toledo, Ohio.

James Vick. See VICK.

Japanese Seedling X. See JAPEX.

Japan Hybrid (No. 3). See AMES.

Japex, 30, tr ×. Originated [1] by Luther Burbank, Santa Rosa, Cal., and sent in the spring of 1893 to the New York Agricultural Experiment Station, Geneva, N. Y. Mr. Burbank kept no record of its parentage, but it appears to be a combination of *triflora* with a native species.

J. B. Rue. See RUE.

Jennie Lucas, 14, 20, 37, an v. Originated at the Mission Valley Nurseries, Victoria County, Tex., and first disseminated in 1879 by Gilbert Onderdonk.

***Jessie,** am. From the Martin Nursery Co., Winfield, Kans., and reported by H. E. Van Deman to be a wild seedling of the *americana* type.

Jewell, 14, 37, mu. A seedling of Wild Goose, grown by H. A. Terry, Crescent, Iowa.

Joe Hooker, 14, 37, am.

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[1] Iowa Agricultural Experiment Station, Press Bulletin No. 29, 1911.

Jones, 10, am. An accidental seedling originated in 1882 with Mrs. H. Jones, Pottawattamie County, Iowa.

Jones Late, 14, am. Introduced by H. A. Terry, Crescent, Iowa.

Juicy, 14, 34, mu × tr. Originated with Luther Burbank, Santa Rosa, Cal., who says it is a cross of Robinson with Botan [Abundance].

Julia, 30, am. Originated with H. A. Terry, Crescent, Iowa.

***July Fourth**. "It is a second-generation seedling from a French-prune, Japan-plum, American-plum cross," according to the originator, Luther Burbank, Santa Rosa, Cal.

***Kaga**, am × s. Originated with N. E. Hansen, Brookings, S. Dak., who says it is the wild plum pollinated with *Prunus simonii*. Introduced in 1909.

***Kahinta**, (mu × tr) × am. Reported by the originator, N. E. Hansen, as a cross of Apple pollinated with Terry.

***Kamdesa**, b × *A. persica*. The originator, N. E. Hansen, says this is a seedling of the sand cherry pollinated with the Opulent peach. Introduced in 1908.

Kampeska, 14, am.

Kanawha, 14, h. Introduced by P. J. Berckmans, Augusta, Ga., who received it from J. S. Downer, of Kentucky, in 1871.

***Kansas Dwarf Sand Plum**, an w. Offered in 1894 by P. Straubler, Naperville, Dupage Co., Ill.

Kathrin, 14, am. Mr. Kerr knows nothing of its origin.

Keith, 10, 14, 30, am. Originated in Delaware County, Iowa, previous to 1888.

***Kelley**, an (?). Originated in South Carolina and introduced by R. Bates, Jackson, S. C. It is offered as a Chickasaw by the Van Lindley Nursery Co., Pomona, N. C.

***Kelsaw**, tr × an v (?). An accidental cross of Kelsey with a native Chickasaw, originated with A. M. Augustine, West Point, Miss.

***Kenyon**. Listed as a native plum by the Michigan Agricultural Experiment Station.

Kicab, 8, mu. Originated with Benjamin Buckman, Farmingdale, Ill.

Kickapoo, 14, am.

Kieth. See KEITH.

***King**, mu. A name, according to D. L. Adair, apparently applied to a seedling of Wild Goose.

King of Plums. See KING.

***Kitty**, am × n. Said to be a cross between Hawkeye and Cheney. Grown by Theodore Williams.

Klondike, 26, am. Grown by J. Wragg & Son, Waukee, Iowa, from seed of De Soto. Introduced in 1897 by W. F. Heikes, Huntsville, Ala.

Klondyke. See KLONDIKE.

Kniedsen's Peach. See KNUDSON.

Knudson, 14, 30, am. Grown by H. Knudson, Springfield, Minn.

Knudson's Peach. See KNUDSON.

Kober, 30, am. Originated with N. K. Fluke, Davenport, Iowa.

Kopp, 14, am. Grown by O. M. Lord, Minnesota City, Minn.

Kroh. See POOLE PRIDE.

Labert. See LAMBERT.

Labert's Red. See LAMBERT.

La Duc. See LE DUC.

Laire, 4, am × an w (?). A wild variety, found near Kirwin, Kans., by Abram Laire, about 1878.

Lakeside (No. 1), 14, h. A seedling from Theodore Williams, Benson, Nebr.

Lakeside (No. 2), 14, h. A seedling from Theodore Williams, Benson, Nebr.

Lambert, 14, am. A seedling from Ontario, Canada.

Lambert's Red. See LAMBERT.

*__Lancaster__, mu × h mi. A variety grown by Charles B. Camp, Cheney, Nebr., and, according to F. A. Waugh, from seed of Wild Goose pollinated by Miner.

Lang, 36, am. Received in 1898 by the South Dakota Agricultural Experiment Station from C. W. H. Heideman, New Ulm, Minn.

Langdon. See LANGSDON.

*__Langsdon__, h. A variety grown in 1869 in the vicinity of Louisville, Ky. D. L. Adair, who describes it, obtained trees from a man who said he got it from Illinois and who represented that it grew wild in that State. The description and figures indicate that it is *hortulana.*

*__Lannix__, mu × tr. From J. S. Breece, Fayetteville, N. C., and believed to be a hybrid of Abundance with Wild Goose.

*__La Prairie__, am. A wild variety, planted by a Mr. Smith, Shopiere, Wis., about 1844, and listed as an *americana* by E. S. Goff.

*__Large Purple__, an w. A variety from the Texas Panhandle, offered by F. T. Ramsey in 1891.

Large Red, 37, am. A specimen was obtained under this name from the Washington Agricultural Experiment Station, Pullman, Wash.

*__Large Red__, an w. A variety from the Texas Panhandle, offered by F. T. Ramsey in 1891.

Large Red Sweet. See PLUNK.

*__Large Yellow__, an w. A variety from the Texas Panhandle, introduced by F. T. Ramsey in 1891.

*__Late Goose__,[1] mu. From Theodore Williams, Benson, Nebr.

Late Klondike. See GOLDEN and SHIRO.

Late Rollingstone, 37, am. A seedling of Rollingstone, grown by O. M. Lord, Minnesota City, Minn.

*__Laura__. Originated by Theodore Williams, Benson, Nebr., and said to be Quackenboss × Red Glass. The latter in turn was originated with Mr. Williams as a supposed cross of Miner with Quackenboss. The originator says of Laura, "Tree apparently pure *americana.*"

Le Duc, 14, 37, am. Found growing wild at Hastings, Minn., and introduced by W. G. Le Duc.

Le Duc Vermillion. See VERMILLION.

*__Legal Tender__, am. Originated under cultivation with H. A. Terry, Crescent, Iowa, and reported by Craig and Vernon to be an *americana.*

Leonard, 14, 37, am. Mentioned by J. S. Harris[2] as a wild seedling from Washington, Fillmore Co., Minn.

*__Leonard__, am. Originated with Charles Gibb, Montreal, Canada, from a wild plum root obtained in Wisconsin. The region indicates *americana.*

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[1] Hedrick, U. P. The Plums of New York, 1911, p. 481.

[2] Harris, J. S. Minnesota Horticultural Society Report, 1891, p. 181.

*__Leopard__, tr × am (?). Originated with Theodore Williams and said to be seed of Botan [Abundance] pollinated with Red Glass. F. A. Waugh says that it is apparently *triflora* × *americana*.

Leptune, 14, h. Said to have been introduced by J. D. Morrow & Sons, of Arkansas.

*__Letta__, am. Found in Buchanan County, Iowa, and introduced by J. Wragg & Sons, Waukee, Iowa.

Lillie, 36, am. Originated with H. A. Terry,[1] who says it is a seedling of Van Buren. He is, however, quoted by F. A. Waugh as saying that it is a seedling of Hawkeye.

*__Lindheimer__, an v. Offered in 1898 as a Chickasaw by F. T. Ramsey, Austin, Tex.

Little, 30, am. From Charles Luedloff, then of Carver, Minn.

Little Seedling. See LITTLE.

Lizzie, 27, am. A seedling of Harrison, grown by H. A. Terry, Crescent, Iowa, and introduced by F. W. Meneray, Council Bluffs, Iowa.

Lockey, 14, am.

Lone Star, 14, an v. Grown by E. W. Kirkpatrick in Texas from wild seed procured in eastern Texas.

Lotta. See LOTTIE.

Lottie, 30, am. A seedling of Van Buren, grown by H. A. Terry, Crescent, Iowa.

Louisa, 14, am. From Missouri.

*__Louisiana__, tr ×. A seedling of a Japanese crossed with a native. Grown by J. L. Normand, Marksville, La.

*__Luedloff__, am. From Charles Luedloff, Cologne, Minn. Listed as *americana* by E. S. Goff.

*__Luedloff Green__, am. Introduced by Charles Luedloff and listed as *americana* by L. H. Bailey.

*__Luedloff Red__, am. Introduced by Charles Luedloff and listed as *americana* by E. S. Goff.

Luedloff's Seedling. See LUEDLOFF.

Macedonia, 14, 37, mu.

Mackland, 14, am.

Macomber (No. 1), 14, am. From a Mr. Macomber, of Vermont.

Macomber (No. 2), 14, am. From a Mr. Macomber, of Vermont.

*__Madam Leeds__. Originated with George Temple, probably of Iowa, and said to resemble Poole Pride in foliage. The material received from Iowa under this name was *americana*.

Mammoth July 1. See CULBERSON.

Manitoba, 14, n.

Manitoba (No. 1), am. A wild variety from Manitoba and listed by J. W. Kerr as an *americana*.

Manitoba (No. 2), 14, am. Grown by N. E. Hansen, Brookings, S. Dak., from Manitoba seed.

Manitoba (No. 4), 14, 28, n. Grown by N. E. Hansen, Brookings, S. Dak., from Manitoba seed.

Manitoba (No. 5), 14, 28, am. Grown by N. E. Hansen, Brookings, S. Dak., from Manitoba seed.

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[1] Terry, H. A. Transactions of the Iowa Horticultural Society, 1893, p. 276.

Manitoba (No. 6), 14, am × n (?). Grown by N. E. Hansen from Manitoba seed. The foliage appears intermediate between *nigra* and *americana*, and is the only variety studied appearing to have such origin.

Mankato, 14, 36, 37, am. Originated on the farm of L. J. Eider, near Mankato, Minn., and introduced by S. D. Richardson & Son, Winnebago City, Minn.

Maquoketa, 14, 30, 34, 36, 37, h mi. Said by H. A. Terry [1] to be a seedling of Miner. Others have said it was found wild along the Maquoketa River in Iowa. This locality is north of the known range of the species, and the origin given by Terry may be the correct one.

Marais des Cygne, 13, am. Introduced by J. W. Kerr, Denton, Md., in 1900.

Maranokita, 29, h.

***Marble**, h × h mi. Originated with A. L. Bruce in Texas and said to be a cross of Miner and Crimson Beauty.

***Marble**, am. Received by J. S. Harris, of Minnesota, from H. Knudson, Springfield, Brown Co., Minn. From the origin and description it is apparently *americana*.

Marcellus, 14, 26, am. A seedling of Van Buren, grown by H. A. Terry, Crescent, Iowa.

Marcus, 14, 36, 37, am. Originated in Cherokee County, Iowa, from seed of fruit found growing on Little Sioux River. It was named for the town from which it was disseminated.

Margaret, 1, tr × an. From seed of Kelsey planted in 1895.

Marianna, 14, an v (?) × c. An accidental seedling on the grounds of C. G. Fitze at Marianna, Polk Co., Tex.

***Marion**, am. A variety grown at one time by J. W. Kerr, Denton, Md., and listed as an *americana*.

***Marjorie**, am. A seedling of Lottie, grown by H. A. Terry, Crescent, Iowa.

***Martha**, tr ×. A variety listed in 1901 by G. Onderdonk as a hybrid of Japanese and native.

Mary, 11, 30, am. A seedling of Van Buren, grown by H. A. Terry, Crescent, Iowa.

Maryland, 14, (b × an w) × am. Grown about 1882 by J. W. Kerr, Denton, Md., from seed of Utah.

Mason, 14, 20, an v. Originated with Messrs. Mason, near Leander, Williamson Co., Tex.

***Mathews**, h. Originated with B. A. Mathews, Knoxville, Marion Co., Iowa. First discovered in a nursery row of root-grafted Peach Leaf plums, the original tree being planted in the orchard about 1886. Listed as *hortulana* by E. E. Little.

Matthews. See MATHEWS.

Maude Lacey, 14, am. A seedling of Hawkeye, grown by H. A. Terry, Crescent, Iowa.

McCartney, 14, 20, an v. A variety grown by F. T. Ramsey, Austin, Tex.

***McKinley**, am. Originated [2] on the farm of a Mr. McKinley, Lucas County, Iowa, and said by M. J. Wragg, Waukee, Iowa, to be an *americana*.

***McPherson**, an (?). A variety grown at the Texas station and from the description probably *angustifolia*.

***McRea**, tr ×. Originated near Lake City, Columbia Co., Fla. It is probably a hybrid of Kelsey with either *munsoniana* or *angustifolia*.

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[1] Terry, H. A. Transactions of the Iowa Horticultural Society, 1890, p. 55.

[2] Wragg, M. J. Transactions of the Iowa Horticultural Society, 1899, p. 161.

Meadow, am. Received by J. S. Harris,[1] of Minnesota, from H. Knudson, Springfield, Minn., and it appears from the account given to be an *americana.*

***Melon**, am. Fruit of this variety was sent to the Iowa station by C. L. Watrous, of Des Moines. It is listed as an *americana* by Craig and Vernon.

Meneray, 27, am × tr (?). A seedling of unknown parentage, grown by H. A. Terry and introduced by F. W. Meneray, Council Bluffs, Iowa.

***Meneray's** (No. 2). Grown by H. A. Terry,[2] Crescent, Iowa.

Meyer, 14, am.

Miles, 30, 34, mu. Said to have originated in Illinois from seed taken from North Carolina.

Miller, 14, am.

***Miller**, tr ×. Introduced in 1907 as a Japanese hybrid by the Glen Saint Mary Nursery Co., Glen St. Mary, Fla.

Miller's (No. 5), 14, an v × mu. Grown by David Miller, Camp Hill, Pa.[3]

***Millett**, am. A variety grown and listed as an *americana* by N. E. Hansen, Brookings, S. Dak.

***Millet Early Red**, am. Found wild near Pierre, S. Dak., and said by N. E. Hansen to be an *americana.*

Millett's Early Red. See Millett Early Red.

Millett T. T., 36, am. A variety grown at the South Dakota Agricultural Experiment Station.

***Millett Very Early Red**, am. Listed by N. E. Hansen as an *americana.*

Millett's Very Early Red. See Millett Very Early Red.

Millett's Wild Plum. See Millett.

***Mills Seedling**, n. Listed by W. T. Macoun as *nigra.*

Milton, 14, 30, 31, 33, 34, mu. A seedling of Wild Goose, grown by H. A. Terry, Crescent, Iowa.

***Minco**, h mi × h. Said by the originator, T. V. Munson, Denison, Tex., to be a hybrid of Miner and Wayland.

Miner, 14, 30, h mi. The seed which produced this variety seems to have been planted in Knox County, Tenn., by William Dodd about 1814. In 1823 or 1824 it was taken to Illinois and later to Lancaster, Wis., where it received its present name from a Mr. Miner.

Minner. See Miner.

Minnesota. See Rollingstone.

Minnesota Seedling, 34, am. A variety from a Mr. Macomber, of Vermont.

Minnetonka, 14, am. Introduced by Peter M. Gideon, of Minnesota.

***Minnie**, tr × mu. From J. S. Breece, Fayetteville, N. C., and said by F. A. Waugh to be probably Abundance pollinated with Wild Goose.

***Mississippi**, mu. Introduced by J. M. Shell, of Georgetown, Tex., about 1875, and listed as *munsoniana* by U. P. Hedrick.[4]

Mississippi Red. See Mississippi.

***Missouri**, h. Said by Professor Newman to resemble Columbia [Cumberland].

Missouri Apricot, 14, 33, 34, h.

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[1] Harris, J. S. Minnesota Horticultural Society Report, 1890, p. 128.
[2] Terry, H. A., catalogue, 1890.
[3] Hedrick, U. P. The Plums of New York, 1911, p. 495.
[4] Hedrick, U. P. Op. cit., p. 497.

***M. J. De Wolf**, am. A variety received by N. E. Hansen September 7, 1904, from M. J. De Wolf, Letcher, S. Dak., who received seedling plums from C. W. Gurney, Yankton, S. Dak. These were grown from pits saved from the orchard of his son, H. J. Gurney, Elk Point, S. Dak., containing mainly such varieties as Hawkeye, Quaker, De Soto, Wyant, Wolf, and Forest Garden. From the account given it appears to be an *americana*.

***Modern Woodman**, mu. A variety offered by the Sunny Slope Nursery, Hannibal, Mo., in 1911, which appears from the description and figure to be *munsoniana*.

Mollie, 14, am. Grown by Theodore Williams, Benson, Nebr.

Molly. See Mollie.

Monolith, 6, tr × mu. Grown by J. S. Breece, Fayetteville, N. C., and apparently intermediate between Abundance and Wild Goose.

***Monon**, am. A variety offered by J. W. Kerr in 1897 as an *americana*.

Monona, 14, 23, am. A variety grown by Christian Steinman, Mapleton, Iowa.

Montbessey, 30, b × *P. cerasus*. A supposed hybrid of *besseyi* with the Montmorency cherry, originated by Theodore Williams, Benson, Nebr.

Moon, 14, 37, am. A variety offered by J. W. Kerr, Denton, Md., in 1894.

Mooreman. See MOREMAN.

Moore's (No. 1), 30, am. A variety grown at the Iowa Agricultural Experiment Station.

Moreman, 14, h. Originated in Kentucky and introduced by W. F. Heikes in 1881.

Moreman Cherry. See AURORA.

Moreman Prune. See BENSON.

Moreman's Cherry. See AURORA.

Motteleigh, 30, am. A variety received from the Iowa Agricultural Experiment Station.

***Mountain Plum.** Said by P. J. Berckmans to be an improved Chickasaw.

Mrs. Cleveland. See CLEVELAND.

Mrs. Clifford. See CLIFFORD.

***Mudson**, an v (?). Listed as a Chickasaw by the Georgia Horticultural Society.

***Muldraugh**, am. Found wild on Muldraugh's Hill in Hardin County, Ky., and said by D. L. Adair to be an *americana*.

Muldraugh's Hill. See MULDRAUGH.

Mule, 14, mu × *A. persica*. From seed of Wild Goose pollinated by Troth Early peach, grown by J. W. Kerr, Denton, Md.

Muncey. See MUNCY.

Muncy, 14, 37, am. An *americana* offered at one time by J. W. Kerr, Denton, Md.

***Muncy**, mu. A selected seedling grown from seed of Poole Pride.[1]

Munson, 14, an v. Originated under cultivation in Texas and introduced by G. Onderdonk in 1888.

***Musquaka.** A variety grown by Prof. James Mathews, who lived in the vicinity of Des Moines, Iowa.[2]

***Mussey**, am. A wild Kansas variety introduced by Abner Allen and listed by L. H. Bailey as an *americana*.

***Native Red**, n. Received by the Fruit Growers' Association of Ontario from W. W. Snelling, of Ottawa. It is probably *nigra*, as Mr. Snelling has been growing this species for a number of years.

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[1] Stark Bros., catalogue, 1910. [2] Transactions of the Iowa Horticultural Society, 1875, p. 235.

N. C. Seedling. See NORTH CAROLINA.

Neals, am. A variety mentioned in 1900 by Joseph Wood, of Iowa, and from the account given it appears to be an *americana*.[1]

Nebraska, 14, 29, h. mi.

***Nebraska Wonder**, am. Found wild in 1892 by A. Webster, Golden, Burt Co., Nebr., and introduced in 1897 by H. P. Sayles, Ames, Iowa. It is listed by Craig and Vernon as an *americana*.

Nellie, 14, am.

Nellie Blanche, 14, 30, am. Grown by H. A. Terry, Crescent, Iowa.

Nelly. See NELLIE.

Neverfail. See NEVER FAIL.

***Never Fail**, am. Purchased from an eastern nurseryman for Wolf, but found not to be that variety. It was introduced by J. S. Haag, Hospers, Sioux Co., Iowa, and listed by Craig and Vernon as an *americana*.

***New American**, am. Listed as an *americana* by N. E. Hansen, Brookings, S. Dak.

Newman, 14, 34, mu. Fruit of this variety was sent in 1867 by D. L. Adair, of Hawesville, Ky., to a Mr. Elliott, Cleveland, Ohio.

***Newton**, am. A variety received by T. V. Munson from Theodore Young, of Wichita Falls, Kans. Mr. Munson says it bears the name of the man who owned the original tree and is of the *americana* type.

Newton Egg. See NEWTOWN EGG.

Newtown Egg, 14, am. Originated with Charles Luedloff, Carver, Minn.

New Ulm, 14, 30, 34, 36, am. A wild Minnesota seedling, introduced about 1884 by C. W. H. Heideman, New Ulm, Minn.

***New Wonderful Dwarf Cherry Tree**, p. Introduced by Martin Kline, of Detroit, Mich., who says it was discovered by him in the Northwest in 1887.

Nimon, 14, h × mu. Introduced by T. V. Munson in 1897 and supposed to be a seedling of Wayland pollinated by Wild Goose.

***Nolan**, mu. Mentioned in 1869 by D L. Adair as apparently one of the Wild Goose seedlings grown about that time.

Nolen Plum. See NOLAN.

Nome, 27, am. Grown by H. A. Terry, Crescent, Iowa.

Nona, 14, tr × an v. Originated with D. H. Watson, Brenham, Tex., and said by F. T. Ramsey to be a hybrid of Kelsey pollinated by a Chickasaw.

Norby, 36, am. Originated with A. Norby, Madison, S. Dak.

***Norby** (No. 1), am. Grown by A. Norby and reported as an *americana* by N. E. Hansen.

***Norby** (No. 11), am. A seedling grown by A. Norby and listed as an *americana* by N. E. Hansen.

***Norman.** Mentioned in 1878 by W. S. Carpenter, Rye, N. Y., as an improved variety of the Chickasaw group.

Normand (No. 5). See ALABAMA.

Normand (No. 15). See LOUISIANA.

Normand (No. 20). See GEORGIA.

North Carolina, 14, am ×. Certainly a hybrid of *americana* with some other form.

North Star, 10, 14, am ×. Originated with Martin Penning, Sleepy Eye, Minn., from seed of Surprise.

[1] Transactions of the Iowa Horticultural Society, 1900, p. 489.

Noyes, 14, am. Originated with a Mrs. Noyes, Springville, Iowa, about 1881, and introduced by a Mr. Osborn about 1888.

Noyes Seedling. See NOYES.

Oatey, 14, 37, am.

Ocheda. See OCHEEDA.

Ocheeda, 14, 32, 34, am. Introduced by H. J. Ludlow, Worthington, Minn., in 1892, and said to have been found wild in 1872 on the banks of Ocheeda Lake, Nobles Co., Minn., by P. L. Hardow.

Odegaard. See ODEGARD.

Odegard, 14, 30, 32, n. Originated at Brookings, S. Dak., about 1887, from pits sent from Minnesota.

Ogeeche, 14, am. Found wild in Georgia and introduced by C. Bourquin.

Ogeechee. See OGEECHE.

Oglesby, 30, am. A variety at one time grown by H. T. Thompson, Marengo, Ill.

Ohio, 14, 20, mu. Catalogued in 1875 by the father of F. T. Ramsey, and thought to have originated in the northern part of Williamson County, Tex. Listed by Mr. Ramsey as belonging to the Wild Goose group.

***Ohio Chief.** A variety offered by the Parsons Nursery Co., Parsons, Kans., and probably a native.

Ohio Prolific. See OHIO.

***Okiya**, b × (mu × tr). Said by the originator, N. E. Hansen, to be the sand cherry pollinated with Gold Plum [Golden].

Old Gold, 14, am. Introduced by C. W. H. Heideman, New Ulm, Minn.

Old Hickory. See MINER.

***Ollie**, h × mu. Originated by A. L. Bruce, in Texas, who says it is a hybrid of Wayland and Wild Goose.

***Olson**, am. Found on the Vermilion River near Vermilion, S. Dak. Its origin indicates that it is an *americana*.

Omaha, 14, am × tr. Originated by Theodore Williams, Benson, Nebr., and said to be a cross of Abundance and Brittlewood.

***Omega**, am. Originated by H. A. Terry, Crescent, Iowa, and listed as an *americana*.

***Opata**, b × (mu × tr). Grown by N. E. Hansen, of South Dakota, from seed of the sand cherry pollinated by Golden and introduced in 1908.

Oren, 30, 34, am. "In the fall of 1876, I came from Benton County to this locality, Spring Creek Township, Black Hawk County, Iowa. Calling on Mr. Bingaman (now dead), I noticed a few young plum trees standing in his garden full of these plums. I bought a farm adjoining Mr. Bingaman; in the fall of 1878 I moved on the farm. Noticing at the edge of some timber and bush a plum tree, apparently very old, that bore these plums (it is now dead) and some young trees standing at some distance from the old tree, I dug up and planted these young trees. From these I plucked the plums I sent you in September." (*Statement of Mr. Oren.*)

Osage, 14, mu.

Osage 48. See OSAGE.

***Owanka**, b × (mu × tr). Originated by N. E. Hansen, Brookings, S. Dak., from seed of the sand cherry pollinated with Golden and introduced in 1908.

Owatonna, 32, am. A wild variety, originated at Owatonna, Minn.

Oxford, 36, n. A Minnesota variety.

***Oxheart**, mu. A variety listed in 1911 by F. T. Ramsey & Son, Austin, Tex., as belonging to the Wild Goose group.

*Oziya, tr × am. Said by the originator, N. E. Hansen, to be Red June pollinated with De Soto.

Pander, 6, tr × h. A seedling of Abundance, grown by J. S. Breece, of Fayetteville, N. C.

***Panhandle**, an w. Listed by F. T. Ramsey in 1899. Its name indicates that it came from the Panhandle region of Texas and would therefore be *angustifolia watsoni*.

Paris Belle. See Texas Belle.

***Parker**, am (?). Reported by Mr. Wedge, of Minnesota, and probably a native.

***Parrott**. Described as a crossbred variety by A. H. Griesa, Lawrence, Kans.

***Parson**. Mentioned by J. Webster, Centralia, Ill. Said to have come from St. Louis, Mo.[1]

Parsons. See Miner.

***Pasqua**. A native Manitoba variety, from Thomas Frankland, Stonewall, Manitoba.

***Patten A**. Originated under cultivation with C. G. Patten, Charles City, Iowa.

***Patten B**, am. Originated under cultivation with C. G. Patten and listed by Craig and Vernon as an *americana*.

Paul Wolf. See Bender.

Peach, 14, am. Grown by H. Knudson,[2] Springfield, Minn., and perhaps the same as Knudson (*Knudson Peach*).

Peachleaf. See Peach Leaf.

***Peach Leaf**, h. A variety grown by B. A. Mathews, Knoxville, Iowa, who states that he obtained it from D. B. Wier, Lacon, Ill., about 1868. The description indicates that it is *hortulana*, and it is so listed by E. E. Little.[3]

Peach-Leaved. See Kanawha.

Pearl, 14, 30, am l. Grown by H. A. Terry, Crescent, Iowa, from seed of Van Buren.

Peerless, 27, am. A seedling of Harrison, grown by H. A. Terry, Crescent, Iowa.

Peffer. See Premium.

Peffer Premium. See Premium.

Peffer's Premium. See Premium.

Pekin, 14, mu (?). Originated by Theodore Williams, Benson, Nebr.

Pendent, 14, mu × am. Originated by Theodore Williams from seed of Pottawattamie pollinated by Forest Garden.

Penning, 14, am. Originated by a Mr. Penning, Sleepy Eye, Minn.

Penning (No. 1), 30, am.

Penning Peach, 14, am. Said by C. W. H. Heideman to have been originally introduced as the Peach plum.

Penning's Peach. See Penning Peach.

Penning's Free. See Penning.

Pennock, 18, b × am. Originated by C. E. Pennock, Fort Collins, Colo., from seed of Rocky Mountain Cherry thought to be pollinated by Moore's Arctic. The seed was planted in 1893. Foliage of this variety indicates that *besseyi* strongly predominates. The other parent is probably *americana*, there being no indication whatever of *domestica*.

Pennock's Hybrid. See Pennock.

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[1] Transactions of the Illinois Horticultural Society, 1888, p. 82.

[2] Minnesota Horticultural Society Report, 1890, p. 125.

[3] Little, E. E. Iowa Agricultural Experiment Station Bulletin 114, 1910, p. 142.

***Perryville.** A native variety, listed in 1893 by H. J. Weber & Sons, St. Louis, Mo. Said to have been found in Perry County, Mo.[1]

Pilot, 14, 34, am. Originated by M. E. Hinckley in 1874 from seed gathered on the Little Sioux River, Cherokee County, Iowa.

Piper, 14, am. Received in the fall of 1889 from J. S. Harris, La Crescent, Minn., who procured it in the vicinity of Mankato, Minn., about two years previously.

Piper's Peach. See PIPER.

Piram, 14, an v. A seedling found in Goliad County, Tex., and named about 1874 after Piram Hall. Introduced by Gilbert Onderdonk.

Plunk, 14, am. Introduced by Charles Luedloff, Cologne, Minn.

***Pomona,** am × h mi (?). Originated by E. D. Cowles, Vermilion, S. Dak., who believed it a natural cross of Forest Garden and Miner.

***Pontotoc,** h. A variety listed in 1898 by F. T. Ramsey, Austin, Tex., as belonging to the Wayland group.

Poole. See POOLE PRIDE.

Poole Pride, 14, 30, 34, 37, mu. Originated by P. H. Kroh, Anna, Ill.

Poole's Pride. See POOLE PRIDE.

Pool's Pride. See POOLE PRIDE.

Pottawattamie, 30, 34, 35, 37, mu. Introduced by J. C. Rice, Council Bluffs, Iowa, in 1875, having come originally from Tennessee.

Potter, 30, am. Originated in Cherokee County, Iowa.

Prairie. See PRAIRIE FLOWER.

Prairie Flower, 14, 29, 37, h mi. Originated in Audrain County, Mo., and supposed to be a seedling of Miner.[2]

***Prairie Rose.** A seedling raised at the experimental farm, Indian Head, Saskatchewan.

Premium, 14, 37, am. Introduced by George P. Peffer, Pewaukee, Wis.

Preserver, 14, tr × an v. Originated by D. H. Watson, Brenham, Tex., and supposed to be from Kelsey seed pollinated with Early Red.

President, 27, am. A seedling of Harrison, grown by H. A. Terry, Crescent, Iowa.

President Wilder. See WILDER.

***Presley,** h mi × h. Grown by A. L. Bruce in Texas, and said by F. A. Waugh to be probably a hybrid of Miner and Wayland.

Price, 27, am. A seedling grown by H. A. Terry, Crescent, Iowa.

Professor Budd. See BUDD.

Professor Craig. See CRAIG.

Professor Goff. See GOFF.

Professor Price. See PRICE.

Profuse, 14, am (?) × h. Originated by Theodore Williams, Benson, Nebr.

Prune Kanawa. See KANAWHA.

Purple Panhandle, 14, an w. Introduced from the Panhandle of Texas by F. T. Ramsey, Austin, Tex.

Purple Yosemite, 14, am. Received before 1878 by W. S. Carpenter, Rye, N. Y., from the Rocky Mountains, under the name Yosemite.

Puzzle, 30, b ×. Originated with Theodore Williams, Benson, Nebr.; of unknown parentage.

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[1] Weber, H. J., & Sons, catalogue, 1893.

[2] Stark Bros. Nursery Co., Fruit and Fruit Trees, p. 23.

Quaker, 14, 37, am l. Found wild by Joseph Bundy, Springville, Linn Co., Iowa, and introduced about 1862 by H. C. Raymond, Council Bluffs, Iowa.

Quaker Beauty, 14, am l. Obtained by J. W. Kerr in 1897 from the Washington Agricultural Experiment Station, Pullman, Wash.

*__Quality__, am. A variety of unknown origin, but grown at one time by Edson Gaylord, Nora Springs, Iowa. Said by E. S. Goff to be an *americana*.

Queen. See GOLDEN QUEEN.

*__Queen of Arkansas__. Mentioned by R. H. Price in an unclassified list at the Texas Agricultural Experiment Station.

Quitaque, 20, an w. A selection from the wild near Quitaque, Tex., introduced by F. T. Ramsey.

Rachel, 14, 29, 37, h mi.

Ragland, 14, tr × an v. Originated with D. H. Watson, Brenham, Tex., and supposed to be a hybrid of Kelsey pollinated with Yellow Transparent.

Rains. See KANAWHA.

*__Ramsey Last__, mu. Originated with F. T. Ramsey, Austin, Tex.[1]

Rang. See LANG.

Rareripe, am. Grown at the South Dakota Agricultural Experiment Station and from the description apparently an *americana*.

Rare Ripe. See RARERIPE.

*__Ray__, h mi × mu. Originated with A. L. Bruce, Basin Springs, Tex., and supposed to be a cross between Miner and Wild Goose.

R. B. Whyte (Nos. 1, 4, and 5), 28, n. Grown by R. B. Whyte, near Ottawa, Canada.

R. B. Whyte (No. 3). See WHYTE.

*__Reagan__, h × am. Introduced in 1907 by the Texas Nursery Co., Sherman, Tex., as Wayland crossed with an *americana*.

Rebecca, 14, am.

Reche, 14, 37, am.

*__Red Chickasaw__, an v (?). Offered in 1891 by the Mallinckrodt Nursery, St. Charles, Mo.[2]

Red Cloud, 14, 37, am.

*__Red Glass__, h mi. Originated about 1894 by Theodore Williams, Benson, Nebr., as a cross between Miner and Quackenboss. It is said by F. A. Waugh to show no evidence of Quackenboss.

*__Red Glass Junior__. Originated by Theodore Williams, who says it is "Blue Glass [Red Glass] × Quackenboss," but that the tree looks like an *americana*.

*__Red Horse__, am. Offered as an *americana* by J. W. Kerr, Denton, Md.

*__Redick__,[3] am.

Red May, 14, 15, 20, tr × mu. A seedling of Abundance pollinated with Wild Goose, originated by A. L. Bruce, Basin Springs, Tex.

Red October, 15, mu (?).

Red October. See WARD OCTOBER RED.

Red Panhandle, 14, an w. Introduced from the Panhandle of Texas by F. T. Ramsey, Austin, Tex.

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[1] Hedrick, U. P. The Plums of New York, 1911, p. 525.
[2] Mallinckrodt Nursery, catalogue, 1891.
[3] Hedrick, U. P. Op. cit., p. 527.

Red Skin, 14, mu. Originated with Theodore Williams, Benson, Nebr.[1]

Reed, 14, 30, h. Originated with O. H. Reed, Hightstown, N. J., from pits obtained in Illinois.

Reel, 14, 30, am. A seedling of Van Buren, grown by H. A. Terry, Crescent, Iowa.

*__Regina__. A seedling grown at the Indian Head Experimental Farm, Saskatchewan.

Reinette, 37, am l.

Rice Seed. See GAVIOTA.

Richey (No. 1), 30, am. A seedling grown in Iowa.

Richey (No. 2), 30, am. A seedling grown in Iowa.

*__Robert__, am. Listed as an *americana* by E. S. Goff.

Robert's Freestone. See ROBERT.

Robinson, 34, mu. Reported as a seedling grown by a Mr. Putnam in Indiana from seed carried with him from North Carolina and brought to notice in 1879 by Dr. J. H. Robinson.

Robinson. See MINER.

Rockford, 14, am. A wild variety, introduced by C. G. Patten, Charles City, Iowa. The original tree came from a grove near Rockford, Iowa.

Rocky Mountain, 14, am. From C. W. H. Heideman, of Minnesota, and listed as an *americana* by F. A. Waugh.

Rocky Mountain Cherry, 14, b. Introduced by Charles Pennock, Bellvue, Colo.

Rocky Mountain Dwarf. See ROCKY MOUNTAIN.

*__Rocky Mountain Seedling__.[2] Mentioned as a native variety in 1882 by Louis Koeper, Marshalltown, Iowa.

Rollingstone, 14, 29, 32, 36, 37, am. Found about 1852 on Rollingstone Creek, Winona County, Minn., by O. M. Lord, Minnesota City, Minn. Introduced about 1882.

Rolling Stone. See ROLLINGSTONE.

Rollingstone Late, 14, am. Grown by O. M. Lord, Minnesota City, Minn., from seed of Rollingstone.[3]

*__Rosselle__, am. A chance seedling, originated in 1892 with Ernest Hoffman, Roselle, Carroll Co., Iowa, and listed an an *americana* by Craig and Vernon.

Roulette, 14, mu. Supposed to have originated in Texas.

*__Round__. A native plum received previous to 1888 by J. Webster, Centralia, Ill., from a Mr. Spears, Cedar Rapids, Iowa.

Rowlett. See ROULETTE.

Ruby, 6, tr × mu. Originated with J. S. Breece, Fayetteville, N. C., and supposed to be a cross of Abundance with Wild Goose.

Ruby, 34, mu. A seedling of Wild Goose, introduced in 1891 by L. T. Sanders of the Orchard Home Nursery, Plain Dealing, La.

Rue, 32, 36, am. Scions of this variety were received by Prof. Budd, of the Iowa Agricultural College, from J. B. Rue, Pottawattamie County, Iowa.

*__Rupert__, p × am. A variety listed by W. T. Macoun, Ottawa, Canada, as a cross between *Prunus pumila* and *P. americana*.[4]

Sada, 14, am. Grown by H. A. Terry from seed of Van Buren.

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[1] Hedrick, U. P. Op. cit., p. 529.

[2] Transactions of the Iowa Horticultural Society, 1882, p. 237.

[3] Kerr, J. W., catalogue, 1899–1900, p. 10.

[4] Macoun, W. T. Central Experimental Farm Bulletin 43, 1903, p. 40.

*__Saffold.__ Introduced into Texas from Alabama about 1853 by General "Safford," of Seguin, Tex. Gilbert Onderdonk says, "It was cultivated long before we had any other plum."

*__Sanders,__ an v. Introduced by J. S. Kerr, Sherman, Tex., in 1898 and classed as a Chickasaw by F. A. Waugh.

*__Sanderson,__ am. A Minnesota variety, listed as an *americana* by J. L. Budd.

*__Sandoz.__ Introduced by E. F. Stephens, of the Crete Nursery, Crete, Nebr., who says it is of northern Nebraska origin.

*__Sansota,__ b × am. Originated with N. E. Hansen, Brookings, S. Dak., who says that it is a sand cherry crossed with De Soto. Introduced in 1910.

*__Sapa,__ b × tr. Originated with N. E. Hansen, Brookings, S. Dak., as a seedling of *Prunus besseyi* pollinated with Sultan. Introduced in 1908.

*__Saskatchewan.__ A native Manitoba seedling, grown by Thomas Frankland, Stonewall, Manitoba.

*__Satin,__ h × tr. Originated by J. S. Breece, Fayetteville, N. C., and believed to be a hybrid of Moreman with a Japanese plum.

Schley, 14, 30, mu. Originated near Augusta, Ga., and introduced by W. K. Nelson, of Georgia.

Schley's Large Red. See SCHLEY.

Schoenthal, 14, am.

*__Scribner,__ mu × tr. Originated with J. S. Breece, Fayetteville, N. C., as a chance seedling; believed to be a cross of Abundance pollinated with Wild Goose.

Seper, 14, am × tr (?). This variety shows no indication of *nigra*, though often referred to that species. The foliage has the acute serrations of *americana*, but shows in the form of the leaf a possible admixture of *triflora*. Introduced by J. W. Kerr.

Seper's Peach. See SEPER.

September, 27, am. A seedling grown by H. A. Terry and introduced by F. W. Meneray, Council Bluffs, Iowa.

*__Shaker.__ Grown by James G. Johnson, Carthage, Ill., from seed brought from Ohio, and apparently a native.

Shanghai (No. 2), 14, am. From Theodore Williams, Benson, Nebr.

*__Shedd Cluster,__ mu (?). A wild variety, found by Mr. Shedd between Lampasas and Coryell Counties, Tex., and said to resemble Robinson.

Shedd's Cluster. See SHEDD CLUSTER.

Shiro, 14, mu × c × (tr × s). Originated with Luther Burbank, who says it is a combination of Robinson, Myrobalan, and Wickson.

*__Sierra,__ su. A native described by S. L. Mathews, Grizzly Flats, Cal., who says its native home is "high up in the Sierras."

Sierra Crimson. See SIERRA.

Silas Wilson, 10, am. A seedling of Hawkeye, grown by H. A. Terry, Crescent, Iowa.

*__Simpson.__ "The original tree was found growing wild in the woods near Alexis, this State" [Illinois].[1]

*__Sioux,__ b. Listed by N. E. Hansen as a variety of *Prunus besseyi.*

*__Sirocco,__ tr × (an v × c). Originated with J. S. Breece, Fayetteville, N. C., who believes it a hybrid of Abundance with Marianna.

Sisson, su. Taken by Mr. Sisson from a wild thicket near the base of Mount Shasta, about one-half mile from the town of Sisson, Cal. The original thicket was visited by the writer in 1911.

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[1] Augustine & Co., catalogue, spring of 1895.

*__Sixby__, am. A variety disseminated by Edson Gaylord, Nora Springs, Iowa, and listed as an *americana* by E. S. Goff.

Six Weeks, 15, an × tr. A variety of Texas origin, supposed to be a cross of Abundance with a native Chickasaw.

*__Skuya__,[1] tr × b. Originated with N. E. Hansen, Brookings, S. Dak., as a hybrid of Red June pollinated with *Prunus besseyi*, not with De Soto, as originally stated. Introduced in 1908.

Sloe, 37, am.

Smiley, 14, mu. Believed to have originated in Alabama.

Smith, 14, 37, am. Grown from seed of Quaker by C. A. Smith, of Caroline County, Md.

Smith Red, 14, n. Sent to the Wisconsin Agricultural Experiment Station for trial, in 1890, by J. F. Gale & Son, then of Waukesha, Wis.

Smith's Red. See SMITH RED.

Snelling, 28, n. Grown by W. H. Snelling, New Edinburg, Ontario, about 1880, from a sprout of a wild tree grown at Gatineau Point, Quebec.

Snooks. See NEW ULM.

*__Snyder__, am. Originated in 1893 with J. A. Fairchild, Coggon, Linn Co., Iowa, from seed of De Soto.

Sophie, 14, 31, 34, 37, mu × h. A supposed cross of Wild Goose pollinated with the German prune and originated with J. W. Kerr, Denton, Md. There is, however, no trace of *domestica* character in the variety, but it shows some indication of *hortulana* parentage.

*__Souris__. A seedling raised at the Indian Head Experimental Farm, Saskatchewan.

*__South Cumberland__. A variety known for 26 or 27 years previous to 1891 in the vicinity of Augusta, Ga.

South Dakota (*No. 8*). See YUTECA.

*__Southern Beauty__. A hybrid, similar in growth and foliage to Mule, according to J. W. Kerr, Denton, Md.

*__Southern Golden__. Listed by the Alabama Agricultural Experiment Station as belonging to the Chickasaw class.

Speer, 14, 37, am. A wild variety, grown by J. A. Speer, Cedar Falls, Iowa.

Splendid, 30, am. Found wild in 1878 by J. K. Teeter, near Magnolia, Harrison Co., Iowa.

*__Springer__, am. A wild variety found by William A. Springer in the vicinity of Fremont, Wis., and sent to the Wisconsin Agricultural Experiment Station in 1890. Listed as an *americana* by E. S. Goff.

*__Stanapa__, b × c a. Originated with N. E. Hansen, Brookings, S. Dak., who says it is sand cherry pollinated with the purple-leaved Persian plum.

State Fair No. 16. See WASTESA.

Steinman, 23, 30, am. Originated in 1883 by Christian Steinman, Mapleton, Iowa, from a mixed lot of seed of De Soto, Quaker, and Forest Garden.

Steinman (*No. 2*). See STEINMAN.

Stella, 14, am. Grown by Theodore Williams, Benson, Nebr.

*__Sterling__, am. Listed as an *americana* by J. W. Kerr, Denton, Md.

*__Stickney__, am. A variety grown by Franklin Johnson, of Baraboo, Wis., and apparently a native *americana*.

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[1] Hansen, N. E. Some New Fruits, circular of the South Dakota Agricultural Experiment Station, spring of 1912.

Stoddard, 10, 14, 30, 32, 34, am. Originated on the grounds of a Mrs. Baker, Jesup, Iowa, and introduced by J. Wragg & Son, of Iowa.

Stoddart. See STODDARD.

Strawberry, 14, an w.

Stumpe. See HOWE.

Sucker State, 14, h. Believed to have come from Illinois.

Sugar Plum, 25, am. A variety received from G. H. Wilson, Hustisford, Wis.

Sunrise, 30, am. A seedling of De Soto, originated at the Central Experimental Farm, Ottawa, Canada.

Sunset, 30, h mi. Originated with C. E. Pennock, Bellvue, Colo.

Surprise, 14, 17, 30, 32, 34, 36, am × h mi. A selection from a number of seedlings grown from pits of De Soto, Weaver, and Miner by Martin Penning, of Sleepy Eye, Minn. It is evidently a hybrid of *americana* and *hortulana mineri.*

Suwanee. See WILD GOOSE.

Swift, 28, am. A seedling of De Soto, grown at the Central Experimental Farm, Ottawa, Canada.

Tarleton, 14, an v × c. A Georgia variety.

Tecumseh, 14, am. Introduced by J. W. Poole, of Indiana, under the name of Hughes Late.

Tenneha, 38, mu.

***Tennessee**, mu. Apparently one of the seedlings of Wild Goose, grown about 1869.

Tennessee Plum. See TENNESSEE.

***Terrell**, tr × an v (?). Originated by J. Terrell, of Hastings, Fla., and believed to be a seedling of Excelsior.

Terry, 14, 32, am l. A seedling of Van Buren, grown by H. A. Terry, Crescent, Iowa.

***Terry De Soto**, am. A seedling of De Soto, grown by H. A. Terry in 1895 and listed by Craig and Vernon as an *americana.*

Terry's De Soto. See TERRY DE SOTO.

***Teton**, am. Found in 1904 in a thicket a short distance from the Missouri River, near Campbell, Campbell Co., S. Dak. Introduced by N. E. Hansen.

Texas Belle, 14, mu. A variety introduced by Dr. W. W. Steele, Paris, Tex., and grown by Stephen H. Turner.

Thousand-and-One, 14, mu.

***Throssel**, am. Found wild on the Des Moines River by Mr. Throssel, near Pierson, Woodbury Co., Iowa, and listed as an *americana* by Craig and Vernon.

***Toka**, am × s. Originated with N. E. Hansen, who states that it is the wild plum pollinated with *Prunus simonii.* Introduced in 1911.

***Tokata**, s × am. *Prunus simonii* pollinated by De Soto, according to the originator, N. E. Hansen.

***Tokeya**, b × s. Originated with N. E. Hansen, who says it is from the seed of *Prunus besseyi* pollinated with *Prunus simonii.*

***Tomahawk**, b. Said by the introducer, N. E. Hansen, to be *besseyi.*

***Tomlingson**, am (?). Listed as a native in 1882,[1] by Louis Koeper, Marshalltown, Iowa.

***Topa**, am. Listed by N. E. Hansen, Brookings, S. Dak., as an *americana.*

Townsend. See MINER.

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[1] Transactions of the Iowa Horticultural Society, 1882, p. 237.

Traer. See DE SOTO.

Transparent. See MACEDONIA.

Transparent. See YELLOW TRANSPARENT.

Trayer. See DE SOTO.

***Trostle**, am. Grown in the vicinity of Kingsley, Iowa, and said by F. A. Waugh to be probably an *americana*.[1]

***Truro**, am × h mi. A seedling of Weaver crossed with Miner, from E. W. Tucker, Winfield, Ill.

***Tucker**, mu. Grown by E. W. Tucker, Winfield, Ill., from seed taken from a cluster containing Weaver, Miner, Wild Goose, and two prune trees. Tree is said to resemble Wild Goose.

***Tudor**, mu (?). Originated on K. L. Tudor's farm in Texas, and from the description it appears to belong to the Wild Goose group.[2]

***Ultra.** A variety grown by J. A. Wood, Windom, Minn., who says it is a hybrid of the sand cherry and plum.[3]

***Underhill Seedling**, mu. Originated on the farm of Dr. Blackman and said to be a cross between Wild Goose and Washington. It is doubtless a seedling of Wild Goose.[4]

United States, 14, am. Originated with Theodore Williams, Benson, Nebr.

Utah, b × an w. Grown by J. E. Johnson at Wood River, Nebr., previous to 1870. Mr. Johnson later moved to Utah and there disseminated the variety.

Utah Hybrid. See UTAH.

***Value**, am. Originated with Theodore Williams, Benson, Nebr.

Van Buren, 14, am. l. A wild seedling, from Van Buren County, Iowa, introduced by J. Thatcher.

Van Deman, 14, am. A seedling of Hawkeye, grown by H. A. Terry, Crescent, Iowa.

Van Dieman. See VAN DEMAN.

Van Houten, 30, h (?) × am. Grown by H. A. Terry, Crescent, Iowa.

Venice, 14, mu.

Venus, 30, mu. Grown by H. A. Terry, Crescent, Iowa.

Vermillion, 14, am. A variety grown at one time by J. W. Kerr, Denton, Md.

Vick, 14, 30, mu. A seedling of Wild Goose, grown by H. A. Terry, Crescent, Iowa.

***Victor.** A seedling grown at the Indian Head Experimental Farm, Saskatchewan.

***Victoria.** Originated with Theodore Williams, Benson, Nebr.

***Victor Sand Cherry**, (b × mu) × d (?). Grown by Theodore Williams, who says it is a cross of sand cherry with Wild Goose, and this again crossed with Quackenboss.

***Violet**, am (?). A native variety, received by J. S. Harris in 1889 from H. Knudson, Springfield, Minn.[5]

***Virgie**, h mi × h. Originated by A. L. Bruce in Texas and believed to be a cross between Miner and Crimson Beauty.

***Wabash.** Reported in 1868 as a native variety grown in Indiana.

***Wachampa**, b × tr. Grown by N. E. Hansen, who says it is a cross of the sand cherry and Sultan plum.

***Waddell**, an v. Listed as a Chickasaw by F. T. Ramsey, Austin, Tex.[6]

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[1] Waugh, F. A. Plums and Plum Culture, 1901, p. 234.

[2] Paris Nurseries, catalogue.

[3] Transactions of the Iowa Horticultural Society, 1899, p. 442.

[4] Munson, J. J., catalogue.

[5] Minnesota Horticultural Society Report, 1890, p. 128.

[6] Ramsey, F. T., catalogue.

*Wady. Apparently a native.

Wady's Early. See WADY.

*Wagner, am. A seedling of Weaver pollinated with a wild variety, grown by J. F. Wagner, Bennett, Iowa, in 1894, and listed as an *americana* by Craig and Vernon.

Wagner (No. 9). See WAGNER.

Wagner (No. 15), 30, h. A seedling grown in Iowa.

*Wakapa, tr × am. According to the originator, N. E. Hansen, a seedling of Red June pollinated with De Soto. Introduced in 1908.

Wallace, 27, am. A seedling of Harrison, grown by H. A. Terry and introduced by F. W. Meneray, Council Bluffs, Iowa.

Waraju, 14, am. Listed by J. W. Kerr, Denton, Md.

Ward October Red, 20, r × me. Found wild near Henrietta, Clay Co., Tex., by Robert Ward and introduced by T. V. Munson about 1902.

*Warner, am (?). A native plum mentioned by the Minnesota Horticultural Society in 1881.[1]

Warren, 30, am. Grown from seed of Hawkeye by H. A. Terry.

*Wastesa, am. Listed by N. E. Hansen, Brookings, S. Dak., as an *americana*.

Watrous. See CAPTAIN WATROUS.

Watson, 14, 20, tr × an v. Originated by D. H. Watson, Brenham, Tex., and believed to be a seedling of Kelsey pollinated with Lone Star.

*Watts. Mentioned by William H. Castle, Canton, Miss., as a seedling grown by Dr. D. S. Watts, of the same county, from a tree of unknown origin on a neighboring farm. From the description it is apparently a native.

Waugh, 14, tr × h. Originated with J. W. Kerr, Denton, Md., from seed of Chabot pollinated with Wayland.

*Waver Bright. A variety offered by the Wichita Nursery, Wichita Falls, Tex.[2]

Wayland, 14, 30, 33, 34, h. A seedling, originated with Prof. H. B. Wayland, Cadiz, Ky., and sent by him to J. S. Downer & Sons, Todd County, Ky., who named and disseminated it.

Wazata, 14, 30, n. A wild Minnesota variety, introduced by Peter M. Gideon, of Minnesota, and W. F. Heikes, of Alabama.

Weaver, 14, 35, 37, am. A wild variety, found wild on Cedar River, near Palo, Iowa, by Mr. Weaver and introduced by Ennis & Patten about 1873.

Welch, 27, am. Grown by H. A. Terry from seed of Hammer.

Welcome, 20, an w. A variety offered by F. T. Ramsey in 1907.

Welcome, 28, am. A seedling of De Soto, grown at the Central Experimental Farm, Ottawa, Canada.

Whatisit, 14, b ×. Grown by Theodore Williams from seed of *Prunus besseyi*.

Whitacre. See WHITAKER.

Whitaker, 14, 30, 37, mu. A seedling of Wild Goose, originated in eastern Texas by J. T. Whitaker.

White Prune, 30, am. Originated with H. A. Terry, Crescent, Iowa.

Whyte, 28, n. Grown by R. B. Whyte near Ottawa, Canada.

Whyte's Red Seedling. See WHYTE.

Wier Large Red. See WIER.

Wier, 14, am. Originated with D. B. Wier, of Illinois.

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[1] Minnesota Horticultural Society Report, 1881, p. 78.

[2] Wichita Nursery, catalogue.

Wier (No. 50), 14, 37, am. Originated with D. B. Wier, of Illinois.

Wier's Large Red. See WIER.

Wier's (No. 50). See WIER (No. 50).

Wilder, 14, mu × h. A seedling of Wild Goose, grown by H. A. Terry, Crescent, Iowa.

Wild Goose, 14, 21, 30, 33, 35, 37, mu. A wild variety originated in Tennessee.

***Wild Goose Improved**, mu. A variety introduced by Stark Bros., Louisiana, Mo., in 1911.

Wildgoose Yellow. See YELLOW WILD GOOSE.

Wildrose, 14, am. A wild Minnesota variety, introduced in 1888 by A. W. Sias, Rochester, Minn.

William Dodd. See MINER.

Williams, 14, 37, am.

Williams (No. 17), 14, am.

Williams (No. 19), 14, am.

Williams (No. 20), 14, am.

***Wilmeth Late.** A variety taken into Texas many years ago from Alabama.

Wilson, 32, am. Reported as a native seedling from Iowa.

Winnebago, 14, 32, am. A variety received by H. A. Terry from Minnesota.

***Winnipeg**,[1] am. A variety grown by N. E. Hansen from pits secured in Manitoba.

Wisconsin Red. See MINER.

Witman, 32, am. Originated by August Witman, Merriam Park, Minn., about 1895.

W. J. Bryan. See BRYAN.

***Wohanka**, tr × am. Originated with N. E. Hansen, who says it is a seedling of Red June pollinated with De Soto.

Wolf, 10, 14, 30, 32, 34, 36, am l. Originated about 1856 on the farm of D. B. Wolf, Wapello County, Iowa, from pits of wild plums.

Wolf Cling. See WOLF CLINGSTONE.

***Wolf Clingstone**, am l. At one time disseminated for the true Wolf.

Wolf Free. See WOLF.

Wolf Freestone. See WOLF.

Wonder. See OSAGE.

Wonder (Nebraska Wonder, of Sayles). See NEBRASKA WONDER.

Wood, 14, 34, 36, 37, am. A seedling from a plum found growing on the bank of the Des Moines River, Cottonwood County, Minn., and introduced by Joseph Wood, of Windom, Minn.

***Wooster**, mu. Referred to the Wild Goose group by F. A. Waugh.

Wooten, 14, 20, 33, mu. A wild variety, found growing in the valley of the Colorado River, Burnet Co., Tex., by F. T. Ramsey in 1876.

Wootten. See WOOTEN.

Worldbeater, 14, 34, h. Grown from seed of a plum found in 1838 by J. H. Tinsley, near Nashville, Tenn., and planted in Lincoln County, Ky. About ten years later trees of the variety were taken to Clay County, Mo., and many years later introduced by Stark Bros.

Worth, 14, am. Originated by Theodore Williams and introduced by J. W. Kerr, Denton, Md.

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[1] Hansen, N. E. Some New Fruits, circular of the South Dakota Agricultural Experiment Station, spring of 1908.

***Wortham.** Originated with John W. Knodle, 3 miles south of Republican City, Nebr., and apparently a native.[1]

Wragg, 27, am. A seedling of Hawkeye, grown by H. A. Terry, Crescent, Iowa.

***Wragg Freestone.** Received from the Wisconsin Agricultural Experiment Station from Edson Gaylord, Nora Springs, Iowa.

***Wyandotte.** A native variety mentioned in 1889 by J. L. Budd.

Wyant, 10, 31, 32, 34, am. Scions of this variety were obtained by J. E. Wyant, of Shellsburg, Iowa, from a tree in his mother's yard at Janesville, which had been transplanted from a wild grove on the Cedar River.

Wychoff, 30, mu. Introduced in 1902 by S. W. Snyder, Center Point, Iowa, who says it came originally from Illinois.

Yates, 14, tr × an v. Originated with D. H. Watson, Brenham, Tex., and introduced by W. A. Yates. It is believed to be a hybrid from Kelsey seed pollinated with Lone Star.

***Yellow Americana**, am (?). Originated with Theodore Williams, Benson, Nebr.

***Yellow Cherokee**, an v (?). A variety offered by A. K. Clingman, Keithville, La.

***Yellow Chickasaw**, an v (?). Offered by the Mallinckrodt Nursery, St. Charles, Mo., in 1891.

***Yellow Oregon**, h. Obtained by the Wisconsin Agricultural Experiment Station from S. A. Mathews, Knoxville, Iowa. From the description and figures given by F. A. Waugh, it is *hortulana*.

Yellow Panhandle, 14, an w. A variety from the Panhandle region of Texas, introduced by F. T. Ramsey, Austin, Tex.

Yellow Sweet, 14, 37, am. A variety of supposed Minnesota origin.

Yellow Transparent, 14, an v. Selected by J. L. Freeman from a seedling orchard of 2,000 trees grown from wild seed in northern Texas.

***Yellow Wild Goose**, mu (?). Said to have been introduced by R. Bates, Jackson, S. C.

***Yellow Yosemite**, am. Received before 1878 by W. S. Carpenter, Rye, N. Y., from the Rocky Mountains, under the name Yosemite. There were two varieties—one purple, the other yellow with scarlet cheek. Both were doubtless *americana*.

Yosemite. See YELLOW YOSEMITE.

Yosemite Purple. See PURPLE YOSEMITE.

Yosemite Yellow. See YELLOW YOSEMITE.

***Yukon.** A seedling raised at the Indian Head Experimental Farm, Saskatchewan.

***Yuksa**, b × ar. Originated with N. E. Hansen, who says it is a sand cherry crossed with New Large apricot. Introduced in 1908.

***Yuteca**, am. Listed by N. E. Hansen as an *americana*.

***Zekanta**, am. Listed by N. E. Hansen as an *americana*.

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[1] Kansas State Horticultural Society Report, 1885, p. 244.

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 173

Contribution from the Bureau of Entomology
L. O. HOWARD, Chief

Washington, D. C. PROFESSIONAL PAPER April 13, 1915

THE LIFE HISTORY AND HABITS OF THE PEAR THRIPS IN CALIFORNIA

By

S. W. FOSTER and P. R. JONES, Entomological Assistants
Deciduous Fruit Insect Investigations

CONTENTS

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BULLETIN OF THE U.S. DEPARTMENT OF AGRICULTURE

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Contribution from the Bureau of Entomology, L. O, Howard, Chief.
April 13, 1915.

(PROFESSIONAL PAPER.)

THE LIFE HISTORY AND HABITS OF THE PEAR THRIPS IN CALIFORNIA.

By S. W. Foster [1] and P. R. Jones,[2] *Entomological Assistants, Deciduous Fruit Insect Investigations.*

INTRODUCTION.[3]

The so-called pear thrips, (*Euthrips*) *Tæniothrips pyri* Daniel, first attracted attention during the spring of 1902 in a prune orchard near San Jose, Cal. Its injuries rapidly increased in the Santa Clara Valley, and the insect spread to other orchard sections in the San Francisco Bay region. Its increasing destructiveness and spread led to the establishment by the Bureau of Entomology of a laboratory in the Santa Clara Valley to determine the life history and habits of the pest and to determine, if possible, measures for its control in orchards. The laboratory thus started during the summer of 1907 was continued to the fall of 1912.

Mr. Dudley Moulton, an agent of this bureau, who, as Santa Clara County entomologist, had previously had experience with the insect, was placed in immediate charge of the work, in which position he continued until September, 1909. During his period of service Mr. Moulton was assisted in the Santa Clara Valley at one time or another by Messrs. C. T. Paine, S. W. Foster, and P. R. Jones.

In the fall of 1908 owing to the rapid dissemination of the pear thrips to the northward an additional laboratory was established in Contra Costa County, with headquarters at Walnut Creek. This work was placed under the immediate direction of Mr. S. W. Foster, who also had charge of operations in the infested counties to the north. During the spraying season of 1909 Mr. Fred Johnson collaborated with Mr. Foster in experimental and demonstration spraying in

[1] Resigned Oct. 10, 1912.
[2] Resigned Sept. 30, 1912.
[3] By A. L. Quaintance, In Charge of Deciduous Fruit Insect Investigations.

orchards, and in July of the same year Mr. E. J. Hoddy was assigned to the Walnut Creek laboratory and assisted in certain cultivation experiments at Suisun in the fall of 1909, and with Mr. R. W. Braucher assisted in the demonstration spraying operations at Suisun and Courtland during the spring of 1910. During the spraying season of 1911 Mr. Foster was assisted by Messrs. E. L. Jenne and R. L. Nougaret.

Upon the resignation of Mr. Dudley Moulton Mr. P. R. Jones was placed in charge of operations in the Santa Clara Valley and was assisted during the spraying season of 1910 by Mr. E. L. Jenne and during the spraying season of 1911 by Messrs. A. G. Hammar and W. M. Davidson.

During the spraying season of 1912, owing to the absence from California of Mr. Foster, Mr. Jones was charged with all of the pear-thrips operations in California and was assisted in the work by Messrs. W. M. Davidson and L. L. Scott, located at Courtland, by Mr. R. L. Nougaret at Suisun, and by Mr. E. L. Jenne at Walnut Creek.

The manuscript for the present report has been prepared as follows: All of the data relating to Contra Costa County and counties to the northward have been prepared by Mr. Foster, the senior author. Report of operations in the Santa Clara Valley, as well as much of the life-history matter, has been prepared by Mr. Jones. The remaining chapters were written jointly by Messrs. Foster and Jones.

Especial acknowledgment is due to the supervisors of Contra Costa County and Santa Clara County for their assistance in furnishing facilities for work during the season of 1909, and for supplementing the bureau's funds before the special appropriation from Congress was available. The bureau desires also to acknowledge its obligations to many orchardists in the thrips-infested territory, who placed at the disposal of the Department of Agriculture their orchards and facilities for experimental and demonstration purposes. The success which many orchardists have obtained in the control of the pear thrips by the adoption of the recommendations of the bureau, as well as the large-scale spraying demonstrations which the bureau has conducted, has fully demonstrated the effectiveness and practicability of the methods recommended. Especial acknowledgment is made also to Mr. W. S. Ballard, of the Bureau of Plant Industry of the United States Department of Agriculture, for much valuable assistance and numerous courtesies rendered during the course of the work at Suisun.

The present paper deals with the life history and habits of the pear thrips, the results of experiments and demonstrations with sprays and other remedial operations having been given in Circular No. 131 of the Bureau of Entomology.

HISTORY.

LITERATURE.

The first reference in literature to the pear thrips is the original description of the insect by Miss M. Daniels in Entomological News for November, 1904.[1] The type specimens were taken on pear near San Leandro, in Alameda County, Cal., for which reason it was given the common name "pear thrips."

Dudley Moulton,[2] in 1905, published the first account dealing with the economic importance of this species. He described its different stages and the nature and extent of injury caused by it, and included a discussion of its life history. No advice was given as to remedial measures, except that early winter plowing was advocated.

The third reference to the pear thrips in literature was by the same author in Bulletin 68, Part I, of the Bureau of Entomology.[3] This contained practically all that was included in the former publication, with additional information accumulated, making a more complete account of the pest. It was illustrated with appropriate figures of all stages, including the eggs and pupa, which had not theretofore been figured. No successful remedial measures, however, had been determined.

The next publication was also by Moulton, and was issued as Bulletin 80, Part IV, of this bureau.[4] It gave an extended account of the life history of the pear thrips, with recommendations for early fall plowing and cross-plowing, to be followed by spraying in the spring for the adult and an application against the larvæ after the falling of the petals. Tables were given showing the actual number of thrips killed in the plowed as compared with the unplowed areas.

The next account was published as Circular 131 of the Bureau of Entomology,[5] and is a concise abstract of the present paper.

The Journal of the South-Eastern Agricultural College, Wye, Kent County, England, No. 19, for 1910 (published in 1911), contains an article by F. V. Theobald[6] dealing with thrips in general, in which this species receives considerable prominence.

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[1] Daniel, S. M. New California Thysanoptera. *In* Entomological News, v. 15, no. 9, p. 294–295, November, 1904.

[2] Moulton, Dudley. The Pear Thrips (*Euthrips pyri*). California State Horticultural Commission, Publication, Sacramento, 1905. 17 p., 8 figs.

[3] Moulton, Dudley. The Pear Thrips. (*Euthrips pyri* Daniel.) U. S. Dept. Agr., Bur. Ent., Bul. 68, pt. 1, 16 p., 8 figs., 2 pls., June 10, 1907.

[4] Moulton, Dudley. The Pear Thrips and its Control. (*Euthrips pyri* Daniel.) U. S. Dept. Agr., Bur. Ent., Bul. 80, pt. 4, p. 51–66, figs. 13–17, pls. 4–6, Sept. 4, 1909.

[5] Foster, S. W., and Jones, P. R. How to Control the Pear Thrips. U. S. Dept. Agr., Bur. Ent., Circ. 131, 24 p., 14 figs., Jan. 9, 1911.

[6] Theobald, Fred. V. Report on economic zoology for year ending Sept. 31, 1910, p. 57–67, fig. 5, Pls. XXV–XXVIII. *In* Jour. Southeast. Agr. Col., Wye, no. 19, 1911.

Also in 1911 Mr. P. J. Parrott[1] published an account of the appearance of this species in New York State, and in January, 1912, he issued a more extended account of the pear thrips in New York.[2]

HISTORY IN ORCHARDS AND DISTRIBUTION.

The first reported injury caused by the pear thrips was noticed in the year 1902, in an orchard owned by Judge S. F. Leib and Mr. G. M. Bowman. This orchard was situated in the Berryessa district of the Santa Clara Valley, near San Jose, and consisted chiefly of the Imperial variety of prunes. The injury was noticed at first on about 20 or 30 acres of the 200 acres of orchard, and the cause of the trouble at that time was unknown. In the spring of 1904 every other row of this orchard was top-worked with sugar prunes, chiefly to secure better cross-pollination with the Imperial variety of prunes, the lack of which was supposed to have been the cause of failure of the crops in the past. During a drive through 100 acres of this orchard the fruit buds were observed to be just beginning to show the white tips of the petals, and the prospects seemed excellent for a good crop. When revisiting the place five days later, the owner found to his utter astonishment that the whole orchard had the appearance of having been scorched with fire and that there was not an average of a dozen blossoms to the tree.

The thrips were discovered this same year (1904) in the orchard of Mr. R. K. Thomas, on Cypress Avenue, near Stevens Creek Road, about 7 miles distant in an air line from the Leib orchard. From these two orchards infestation has, with the exception of a few acres, spread all over the Santa Clara Valley and into other valleys surrounding the San Francisco Bay.

No exact information is available as to the first appearance of the thrips in other counties, but many orchardists claim that it has been in Contra Costa County since 1904 and in Solano County at least since 1906. In addition to these centers of infestation in Santa Clara, Contra Costa, and Solano Counties, the insect is now present in considerable numbers in Alameda, Sacramento, Yolo, Napa, Sonoma, San Joaquin, and San Benito Counties. The general area of infestation in California is indicated in the accompanying map (fig. 1).

There have been several reported outbreaks of this species in other parts of the State, notably from the Sïerra Nevada foothills near Newcastle and Auburn, near Red Bluff and Anderson in the Sacramento Valley, and from the fruit districts of Tulare and Fresno Counties in the San Joaquin Valley. The species in question, how-

[1] Parrott, P. J. Occurrence of *Euthrips pyri* Daniel in New York State. *In* Science, n. s., v. 34, no. 864, p. 94, July 21, 1911.

[2] Parrott, P. J. The Pear Thrips. N. Y. Agr. Exp. Sta., Geneva, N. Y., Bul. 343, p. 341–366, 4 figs., pls. 30–33 and 1 col. pl., Jan., 1912.

ever, were found to be (*Euthrips*) *Frankliniella occidentalis* Pergande and (*Euthrips*) *Frankliniella tritici* Fitch, neither of which is particularly injurious to deciduous fruits. Reports of injury supposed to have been caused by this species were received from the Rogue River Valley in Oregon, but a critical examination, in 1909, showed no signs of the work of the pear thrips. In the spring of 1910 many larvæ of (*Euthrips*) *Frankliniella tritici* were found, but none of the species under consideration could be obtained.

Not until the year 1911 was the pear thrips positively known to be present in the United States outside of the infested districts of California. However, in the spring of 1911 Mr. P. J. Parrott found it in considerable numbers around Germantown and other points along the Hudson River in New York.[1] Later in the year specimens of (*Euthrips*) *Tæniothrips pyri* were found among some Thysanoptera which had been collected in the spring by Mr. Parrott in the vicinity of Geneva, N. Y.

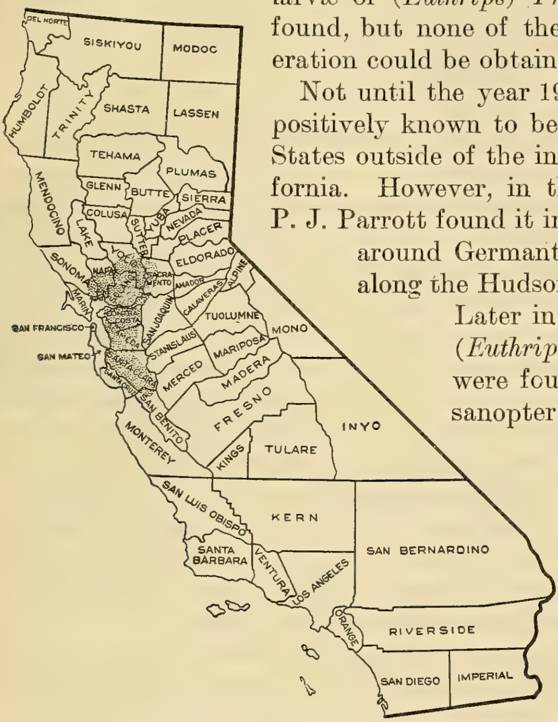

FIG. 1.—Map showing general area of infestation by the pear thrips in California. (Authors' illustration.)

In May, 1912, Mr. A. L. Quaintance sent the authors a number of specimens of thrips collected in pear blossoms from six different orchards by Mr. Fred Johnson at North East, Pa. All proved to be the pear thrips, (*Euthrips*) *Tæniothrips pyri*.

In 1909 Bagnall[2] reported that numerous examples of this very injurious species, taken in plum blossoms at Evesham, England, had been sent to him by Mr. Walter Collinge. So far as we know, this and the previously mentioned account by Theobald are the only published reports of the occurrence of this species outside of the United States.

Two other species of Thysanoptera (*Thrips physapus* L. and *T. flava* Schrank) are mentioned by Carpenter as the "pear-blossom thrips"

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[1] Parrott, P. J. Occurrence of *Euthrips pyri* Daniel in New York State *In* Science, n s., v. 34, no. 864, p. 94, July 21, 1911.

[2] Bagnall, Richard S. A contribution to our knowledge of the British Thysanoptera (Terebrantia), with notes on injurious species. *In* Jour. Econ. Biol., v. 4, no. 2, p. 33–41, July 7, 1909.

in his report before the Royal Dublin Society for 1900,[1] and as the "pear thrips" in his report to the same society for 1901.[2] In the report for 1900 he states that these two species were found feeding in unopened pear blossoms near Dublin, and he attributes the failure of the fruit that season to the work of these insects. The report for 1901 states that a Dr. Barton tried a dressing of kainit around the trees, with very satisfactory results.

In December, 1914, Mr. W. M. Scott[3] reported the occurrence of the pear thrips in a Kieffer pear orchard near Baltimore, Md. The insect was so abundant as completely to destroy the crop of fruit.

THEORIES AS TO ORIGINAL HOME.

Various ideas have been advanced as to the original home of the pear thrips. Dr. Pietro Buffa, a well-known student of Thysanoptera, in private correspondence under date of April 17, 1909, suggested that while it is a good species it should be put only in the genus Physopus, and expressed the belief that it was not a European species. Prof. Silvestri suggested that it was introduced from China or was of other oriental habitat. Several leading fruit growers have expressed the belief that the insect was introduced into this country from France or England, giving as the reason its apparent partiality to prunes, which are varieties of European plums.

The occurrence of the pear thrips in England lends some weight to the theory that it is of European origin. It may be that natural conditions hold it in check in England and that its advent into California under conditions more suitable for its rapid increase explains its presence there in such enormous numbers. Now, however, that its presence is definitely established in the eastern United States, it is probable that the insect had been in this country for years before it was discovered.

It may be possible that the pear thrips is native to the Santa Cruz Mountains, with some wild rosaceous plant as its original food plant. Upon this supposition it is probable that it has been present in the Santa Clara Valley for many years, and that it first became notoriously destructive with the advent of favorable conditions. While this species has been taken upon a great variety of plants and has been found to be able to subsist on many of them, it is distinctly an enemy of deciduous fruits, to which it shows a decided preference.

COMMON NAMES.

Many common names have been assigned to this insect, as "pear thrips," "prune thrips," "cherry thrips," etc. The first mentioned,

[1] Carpenter, G. H. Report on economic entomology for the year 1900, p. 96–97. Reprinted from the Report of the Council of the Royal Dublin Society for 1900.

[2] Carpenter, G. H. Injurious insects observed in Ireland during the year 1901, p. 153–154. *In* The Economic Proceedings of the Royal Dublin Society, v. 1, pt. 3, no. 5, July, 1902.

[3] Jour. Econ. Ent., v. 7, No. 6, p. 478–479, Dec., 1914.

namely, "pear thrips," has been more extensively used, following the original designation of the insect, because the species was first described from specimens taken upon pear trees. The word "thrips" is a general term for the species of the order Thysanoptera and is sometimes erroneously applied to certain other insects, as the grape leafhopper (*Typhlocyba comes* Say). The word "thrips" is both singular and plural.

ECONOMIC IMPORTANCE.

DESTRUCTIVENESS.

This minute insect, which until 1904 was unknown to science, is at present one of the most important insect pests with which the growers of deciduous fruits in the San Francisco Bay region and adjoining counties have to contend. The rapidity with which the insect spreads, its suddenness of attack and complete blasting in a few days of all prospects for a crop of fruit, and the difficulty experienced in its control, combine to make its subjugation a matter of considerable difficulty. Moreover, as the insect is each year developing an ability to subsist on other and new food plants, its capabilities for dissemination become correspondingly increased. There is no reason to believe that the thrips will disappear in a few years, and it should be at once realized that only the most careful attention each year to necessary control measures will make it possible to continue the profitable culture of fruit in regions where this insect is present in any considerable numbers.

In the Santa Clara Valley this insect has been worse some years than others, notably in 1905, 1907, 1908, 1909, and 1910, but it is safe to say that from now on the maximum prune crop possible for this valley will never again be reached unless every orchardist does the utmost in his power to control the thrips. While it may be possible for unfavorable weather conditions to reduce the possibility of a good crop of 100,000,000 pounds of dried prunes for this valley to something like 40,000,000 or 50,000,000 pounds, the thrips, in a great measure, has been responsible for the small crops since 1907, and will continue to be so, first, by killing the fruit buds before they bloom; secondly, by depositing the eggs in the fruit stems, and, thirdly, by the feeding of the larvæ on the fruit, causing it either to drop prematurely or to develop misshapen and scarred on the trees. While the thrips is doing much serious work in the Santa Clara Valley to cherries and pears and the damage done to different varieties of peaches is increasing, yet on account of the small acreage of these fruits the chief loss from a commercial standpoint is to the prune industry. Some idea of the destruction caused by the pear thrips during the previously mentioned bad years may be gained from the following figures, giving the approximate yield of prunes in pounds each year for the years 1900 to 1912, inclusive.

TABLE I.—*Yield of prunes for the Santa Clara Valley, 1900–1912, inclusive.*

Season.	Yield of dried fruit.	Season.	Yield of dried fruit.
	Pounds.		*Pounds.*
1900	120,000,000	1907	50,000,000
1901 [1]	35,000,000	1908	40,000,000
1902	120,000,000	1909	85,000,000
1903	90,000,000	1910	35,000,000 40,000,000
1904	100,000,000		
1905	50,000,000	1911	100,000,000
1906	120,000,000	1912	65,000,000

[1] Severe frost.

In 1911 the pear thrips probably caused a heavy loss in spite of the fact that there were not more than one-half as many thrips present in this valley as in 1910. The good prune crop in the Santa Clara Valley in 1911 was due to light thrips injury and the very heavy rainfall. The amount of rainfall, which was about 8 inches more than the normal, not only placed the trees in excellent shape to bear a heavy crop, but, coupled with other climatic conditions during the early part of 1911 and latter part of 1910, lessened the work of the thrips very materially. Notwithstanding a favorable fruit year from a weather point of view, thrips in some places caused a great amount of damage. The thrips damage in the Santa Clara Valley for 1910 was caused principally by the adults, with very little larval work, while for 1911 it was just the reverse, the adults doing comparatively little injury because of less numbers and strong fruit buds as a result of the heavy winter rains. The scarcity of adult thrips in 1911 may have been due to several causes. Two heavy rains during the early part of April of the previous year knocked off many young larvæ before they were sufficiently mature for transformation. In addition the season for pupating, June to December, 1910, was abnormally dry, showing a deficiency in rainfall of 5.28 inches, while the emergence period in the spring of 1911 was unusually wet and cold. All of these conditions caused a higher mortality than would be the case under normal conditions. However, in orchards which showed comparatively few adults the larvæ were sufficiently abundant to riddle the foliage and cause much of the young fruit to drop. The heavy rains during the emergence period also checked to some extent the work of the adults.

In estimating the economic loss to the fruit industry of California caused by the pear thrips it is necessary to begin with the year 1904, when it was first known that the insect was doing commercial damage, and continue down to the present time. An attempt will be made to give a fair estimate of the amount of damage done yearly to the prune industry alone in the Santa Clara Valley for the years 1904 to 1911, inclusive.

The average size of prunes grown in the Santa Clara Valley is 60–70; that is, dried prunes requiring from 60 to 70 to make a pound. The price paid for prunes during the years from 1904 to 1911, inclusive, was variable, but would average close to a 3-cent basis; that is, 3 cents per pound for dried prunes running 80 prunes to the pound. In order to be conservative, the average size, 60–70, is disregarded, and the loss is figured on the regular 80-to-the-pound basis. In 1904 the loss was estimated at 500 tons, or 1,000,000 pounds (dried prunes), which, at 3 cents per pound, amounts to $30,000. For the year 1905 it was placed at 10,000,000 pounds and the damage at $300,000; in 1906 at 5,000,000 pounds, worth $150,000; in 1907, 15,000,000 pounds, worth $450,000; in 1908, 20,000,000 pounds, worth $600,000; in 1909, 30,000,000 pounds, worth $900,000; in 1910, 40,000,000 pounds, worth $1,200,000; and in 1911, 20,000,000 pounds, worth $600,000. The total of all of these years would be 141,000,000 pounds, valued at $4,230,000.[1] The estimates for some years probably have been close to the actual damage done, but more frequently the loss has undoubtedly been underestimated. In 1904 all the fruit of one orchard, comprising 100 acres of Imperial prunes, was totally destroyed, and this alone at an average crop of 5 tons of green prunes per acre, on a 3-cent basis for dried prunes, would have been valued at close to $30,000, because of the large size of this variety of prune, only from 30 to 40 of which make a pound.

In estimating this loss no account is taken of the great depreciation in value of the crop caused by scabbing. The entire yield each year has been counted as merchantable fruit, and estimates of damage made solely from orchards showing total loss or a marked reduction in tonnage produced.

To explain more fully the commercial quotation of a 3-cent basis, it is meant that 3 cents per pound will be paid for dried prunes averaging 80 prunes to the pound. For prunes which are larger and free from scab or defects the price is usually $1 per ton more for each point in size, and for smaller prunes the price decreases correspondingly.

As to the extent of the damage the pear thrips will cause in this county if left unchecked, it is difficult to estimate, but the fact that thrips were twice as numerous in 1910 as in 1909 shows their ability to double the damage performed in any preceding year. The cause for the notably light prune crop in 1910 is not attributed altogether to the work of the pear thrips, but partly to unfavorable weather conditions, which pervented many of the blossoms from setting fruit. However, all the large producing prune districts of the Santa Clara Valley were very seriously injured by the pear thrips, and hundreds

[1] These estimates are based on fuller and more complete reports than could be obtained in time for Circular 131 of the Bureau of Entomology, and these figures more nearly represent the actual loss.

of acres in these districts were prevented from blooming—a fact not attributable to unfavorable weather conditions but solely to ravages of the thrips. Other orchards, under same weather conditions but with little or no thrips injury, produced a full crop of blossoms.

During the year 1911 another type of injury that was different from previous years, which may be called cumulative injury, was noticeable in many orchards. Barring the three heavy frosts in April, the blooming and fruiting season in 1911 was exceedingly favorable in so far as climatic conditions were concerned. Nevertheless about the 1st of May the trees in many orchards turned a sickly yellow owing to the work of the thrips in 1911 and from devastations by this insect in previous years. Some orchards which were out of the frost belt and which were not severely injured by thrips in 1911 showed this condition noticeably. It is possible that much of this was due to neglect of the orchards by fruit growers who did not obtain crops of fruit during the preceding four years because of the injury of the thrips to the buds, blossoms, and young fruit.

As mentioned before, practically all of the Santa Clara Valley came into full bloom in 1911 and gave promise of a record crop, but larval injury was very heavy over the entire valley. This, with the result of injury in previous years, apparently greatly weakened the trees and caused much of the fruit to fall at the first unfavorable weather.

Injury to pears in the Santa Clara Valley has never risen to great proportions from a financial point of view, for the reason that most of the acreage of this kind of fruit is set out near Santa Clara and Alviso, sections of this valley where the thrips has not yet become dangerously numerous. However, during the season of 1911 a number of orchards in these localities became badly infested. The amount of damage done to cherries in this valley has not been determined on account of the scattered acreage planted to cherries in the infested area.

The distinctly severe years for thrips injury in Contra Costa County in pear orchards were 1908 and 1910, when the crops were practically annihilated. Also there was great loss the two previous years, 1906 and 1907. The prune orchards suffered in these years and in the year 1909, producing less than one-third of a normal crop any one year. The fruit crop has been seriously menaced each year since 1905, the area increasing yearly, and in 1911 it aggregated a total loss to the county of between $1,000,000 and $1,250,000.

Solano County has in some ways been more fortunate, as the thrips has been known to cause serious injury only since 1907, but even in that time the thrips has spread rapidly and caused great damage on large areas; the damage in 1911 was very extensive and the total

loss to the county attributable to the work of the pear thrips amounted to at least $750,000.

The damage in Sacramento County was noticeable only in a comparatively limited area in 1909, increasing considerably both in area and destructiveness during 1910 and 1911, and the total loss to that county probably amounted to at least $250,000.

No accurate figures are available for the damage caused in Alameda County, but a considerable area has been infested for several years and many conservative estimates put the total loss to, but not including, 1912, as more than $150,000.

The pear thrips has more recently been found in slightly injurious numbers in Yolo and Napa Counties, in the eastern part of Sonoma County, in the northwestern part of San Joaquin County, and in some parts of San Benito County.

Including the infested areas in Santa Clara, Contra Costa, Solano, Sacramento, Alameda, Yolo, Napa, and Sonoma Counties, it is safe to say that the thrips, in absence of treatment, would cause an average yearly loss of over $2,000,000. With each additional year an additional loss of several hundred thousand dollars, due to the increase of the area infested and the increased losses in the areas previously infested, is to be expected. The total damage to the fruit industry of the State of California since the first appearance of the insect aggregates, it is believed, at least $6,630,000 up to but not including 1912.

FOOD PLANTS.

While the pear thrips is distinctly a deciduous-fruit insect and practically all of its damage is confined to this class of plants, it has been found upon a great variety of plants the list of which is increasing each year. The fact of its wide range of food plants makes extermination practically impossible, whereas control can be readily practiced. It has been taken upon the following plants and could probably subsist upon a number of them long enough to make it a constant menance to the fruit industry of California: Apricots, apples, almonds, cherries, figs, grapes, pears, plums, prunes, walnuts, madroña (*Arbutus menziesii*), wild California lilac (*Ceanothus thyrsiflorus*), poison oak (*Rhus diversiloba*), dogwood (*Cornus* sp.), acacia, willow (*Salix* sp.), laurel (*Umbellularia californica*), mustard (*Brassica nigra*), live oak (*Quercus wislizeni*), miner's lettuce (*Montia perfoliata*), and various grasses and weeds.

CHARACTER OF INJURY.

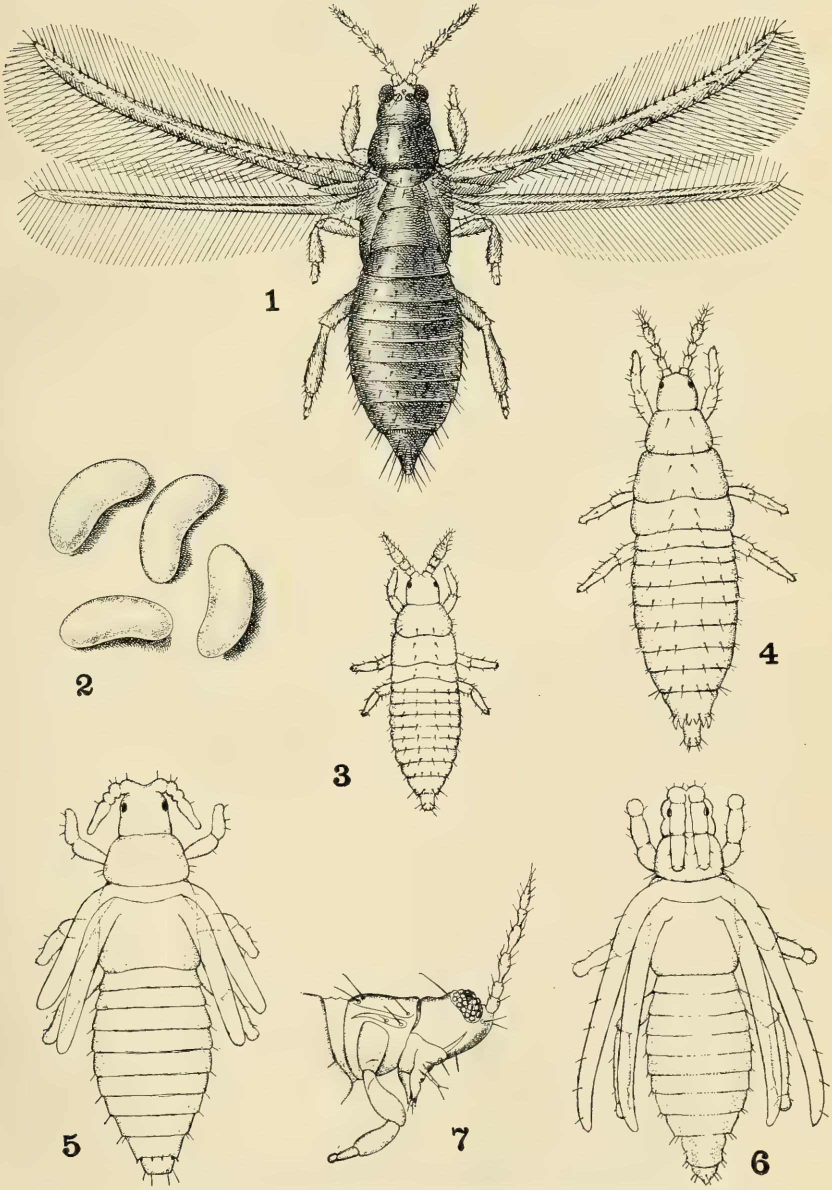
MANNER OF FEEDING AND TYPE OF MOUTHPARTS.

Injury to plants by the pear thrips is caused directly by the feeding of the adults and larvæ upon the various portions of the fruit, buds, flowers, and leaves, and also by the deposition of eggs in the leaf surfaces, fruit stems, and newly formed fruit.

The mouthparts of the Thysanoptera present many difficulties for study and are not thoroughly understood. They are so modified that various writers have disagreed regarding their homologies. They appear, however, to belong chiefly to the suctorial type, and they show many traces of a transition from the mandibulate type to the suctorial. (See Pl. I, fig. 7.) Viewed as a whole, the mouthparts appear as a broad and jointed cone attached to the posterior edge of the underside of the head and resting for a large part under the pronotum. The apex of the cone is quite sharp, but not so slender and drawn out as in the Hemiptera. The mouthparts as a whole are strikingly unsymmetrical. The most evident marks of this are the forms of the labrum and the left mandible. The first, which makes the front wall of the cone, is unsymmetrical in the whole order, but especially so in the Terebrantia. It is irregularly triangular in form and is attached by its broad base to the clypeus. It becomes narrower as it approaches the tip and is usually rounded in the Terebrantia but more variable in the Tubulifera, where it is pointed in some species and broadly rounded in others. The maxillæ are broad and flat and constitute the side walls of the mouth cone. They also taper toward their tips. The labium forms a hind wall of the mouth cone and is usually considerably broader at the tip than at the other parts. Within this hollow cone lie the piercing organs, which are three in number. First, there is a single large mandible lying on the left side of the mouth cavity, whereas the right side has no corresponding member.[1] The other two organs are the maxillary lobes. These are more slender and longer than the mandibles and are developed alike on each side. All of the mouthparts are strongly chitinized at the tip, being more so in the adults than in the larvæ although the mouthparts of the latter are otherwise closely similar to the former.

The members of this order are thought to use the mandibles for piercing the exterior portion of the plants, while the maxillary lobes, which are longer, are used to penetrate deeper into the tissues, and are moved with a rasping motion, causing the juices of the plant to flow, so that they may be sucked up into the alimentary canal. In feeding, as observed by aid of a hand lens, both adults and larvæ exhibit an up-and-down motion of the head combined with a forward motion which might be properly termed rooting. Most of the species under the writers' observation prefer to enlarge a wound into the plant tissues where the juices flow more readily rather than to select new areas for feeding. This continual macerating of the fruit by the pear thrips for a period of several days causes on deciduous fruits what is known as the characteristic pear-thrips scab, which

[1] The mandible in the Tubulifera is shorter and more bent than in the Terebrantia.



THE PEAR THRIPS (TAENIOTHRIPS PYRI DANIEL).

FIG. 1.—Adult. FIG. 2.—Eggs. FIG. 3.—First-stage larva. FIG. 4.—Full-grown larva. FIG. 5.—Pupa, first stage. FIG. 6.—Pupa, last stage. FIG. 7.—Side view of head showing mouth parts. All greatly enlarged. (Original.)

FIG. 1.—MATURE PEAR SHOWING INJURY RESULTING FROM FEEDING OF LARVÆ OF THE PEAR THRIPS. (ORIGINAL.)

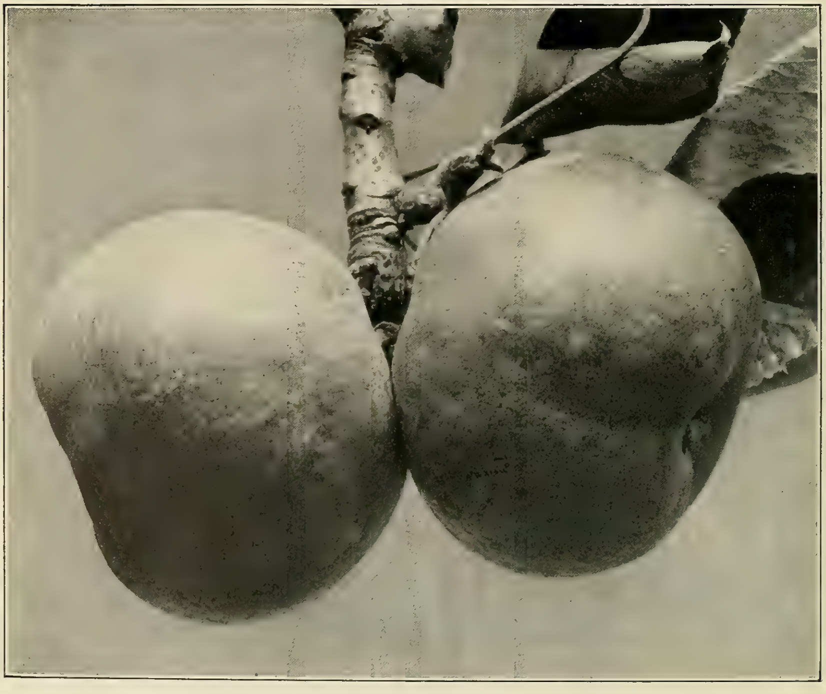


FIG. 2.—TOMATO-SHAPED PEARS RESULTING FROM FEEDING BY ADULT PEAR THRIPS IN THE FRUIT BUDS BEFORE BLOOMING. (ORIGINAL.)

INJURY TO PEARS BY THE PEAR THRIPS.

is very noticeable when the fruit is picked in the fall. Although at this time the insects in question have been in the ground three or four months, the injury becomes more apparent with the maturity of the fruit, and the scabbing or scarring shows as the result of the early spring feeding by this species.

The most serious injury to deciduous fruits by the pear thrips is caused, first, by the feeding of the adults; secondly, by the feeding of the larvæ, and thirdly, by the deposition of eggs in the plant tissue by the adults. The effect of this last injury is more apparent upon the fruits of prunes and cherries than upon the other deciduous fruits. Numerous cases have been observed by the writers in both prune and cherry orchards where the trees blossomed heavily and there was promise of the setting of a good crop of fruit, but where practically all the fruit dropped, solely from the effect of having too many eggs deposited in the fruit stems, thus weakening the tissues, and because the larvæ, feeding directly on the fruit and foliage, so weakened the tree that it would not support a heavy crop of fruit. Perhaps the chief injury to cherries is caused by the deposition of eggs in the fruit stems. The long and tender stem of the cherry presents a most favorable place for the deposition of a great number of eggs.

Injury to the various fruits by adults and larvæ is different, but, classed in regard to bud structure, those fruits in which only a single blossom is produced in a fruit bud, such as the almond, apricot, and peach, seem to be less liable to severe injury than are the fruits which which form a cluster of blossoms amd later produce a cluster of fruits, such as pear, prune, cherry, and apple. If the thrips had their choice of food plants, pears would probably be attacked first in the spring and destroyed; also, other things being equal, a given number of thrips would do more injury no doubt in a pear orchard than in a cherry or prune orchard.

INJURY TO PEARS.

The greater injury to pears is caused by the feeding of the adults in the bud clusters before blooming. Coming out of the ground in great numbers in the spring as the fruit buds are swelling, the thrips soon work their way underneath the bud scales and there attack the individual buds. The feeding is not a biting and chewing process, but the thrips, by rasping the tender surfaces in the developing buds with their hardened or chitinous mouthparts, rupture the skin, and the exudation of sap begins. If only a few thrips are present this injury may be slight and the buds may develop and bloom, producing fruit of normal size, although sometimes short-stemmed, or scarred and misshapen. (See Pl. II, fig. 1.) Plate II, figure 2, shows two Bartlett pears which grew from a cluster that was badly injured but

not entirely destroyed. Plate III, figure 1, shows a mature Bartlett pear the one-sided appearance of which was caused partly by adults and partly by larvæ. When thrips are more numerous a greater amount of the bud surface is injured, consequently there is a greater loss of sap. If this loss is sufficient to cause the cluster buds to "bleed" (sap to drop from the end), fermentation quickly sets in and the entire cluster is soon destroyed. (See fig. 3, in comparison with fig. 2, which shows the cluster buds developing normally.) In many cases blue molds gain a foothold in this fermenting sap and greatly accelerate the injury, causing complete destruction of all fruit buds. The dead clusters later dry up without opening. (See Pl. III, fig. 1, and compare it with Pl. III, fig. 2, which is from a photograph of the sprayed portion of the same orchard, taken on the same day.) These dead buds may remain on the trees for months unless washed off by rain or blown by winds. The writers have seen many orchards so severely injured that it was difficult to find a single healthy blossom, and the entire orchard from a distance presented at blossoming time a brownish color and dead appearance, due to these blasted buds.

FIG. 2.—Cluster buds of Bartlett pears developing normally. (Original.)

Weather conditions influence to a great extent the destruction following the injury caused by the thrips. For instance, the weather of 1909 in the interior valleys during late February and the first 20 days of March was open and comparatively dry, with more or less wind blowing, giving quick evaporation throughout the day. Many clusters of buds that were kept under observation throughout the season, with from 10 to 20 thrips in the cluster, developed many of their buds and produced fruit, a large percentage of which was first class. During this period for 1910 there was considerable rain and the atmosphere was warm and humid with very light evaporation. From many observations in Contra Costa and Solano Counties it was shown conclusively that in every case where as many as 10 to 15 thrips

gained entrance into the bud cluster early in the season, and were left unmolested, the entire cluster was sufficiently injured to prevent the appearance of a single blossom. In 1909 there was greater evaporation, comparatively little of the characteristic bleeding showed at the tips of the buds, and far less of the blue molds appeared in any place. Also the thrips came out of the ground more slowly than in 1910. The latter year thrips were held back to a slight extent by cold wet weather, but once the emergence from the ground commenced, thrips came very rapidly. Then, too, they were more numerous throughout the entire section in 1910 than they were the previous year.

Fig. 3.—Work of the pear thrips on pear at San Jose, Cal. (Original.)

The serious nature of this insect can be understood when it is realized that in a badly infested pear orchard it is far more usual to find from 75 to 150 and often as high as 200 thrips to the cluster than only 10 to 15. Any spraying to be effective must be done before these thrips have remained long, in numbers, inside the bud clusters. A delay of four or five days in spraying the badly infested orchards in the spring of 1910 meant the loss of the entire crop, and in many cases a delay of two to three days for the first application meant a loss of more than half the crop.

In the ability completely to destroy the crop the adult is of more importance than the larva, and in many large orchards the destruction of the developing fruit buds by the adults has been so complete that by the time the trees would normally come into bloom there was left no possibility for a crop of fruit. The larva, together with the injury which has been caused by the deposition of the eggs by the adult, can lessen the prospects of a good crop of fruit after it has apparently set. To secure the best results it is always desirable first to apply efficient treatment against the adult in order to reduce the early injury to a minimum so that the trees may bloom, and later, to make additional treatment against the larvæ. This will usually result in increasing the value of the crop from 10 to 25 per cent for

pears and 40 to 50 per cent for prunes. If remedial measures are not successfully used against the adult but only against the larvæ, it is not to be expected that 50 per cent of a crop will be saved; but the additional treatment against the larvæ after the adult treatments have been applied will cause from 10 per cent to 50 per cent more of the crop to remain on the trees. Without taking into account the after effects of migration, good results can be had in pear orchards by spraying against adults alone, if thorough work is done at the proper time.

INJURY TO PRUNES.

Next to the pear, thrips injure prunes most severely; and, as the larger fruit area in the Santa Clara Valley is devoted to this kind of fruit, and since the pear thrips has caused the failure over large areas of the prune crop for several years, growers in the Santa Clara Valley have commonly called this particular species the prune thrips. The large acreage of prunes and the general distribution of the pear thrips over the valley, together with the fact that the majority of the thrips are out before many of the buds of the French prunes have started to spread, make it very evident that these little insects, which are waiting on the outside of the twigs in enormous numbers, will at the first sign of life of the prune buds bury themselves into the very heart of the tenderest parts, and rapidly carry on their work of destruction. The numbers that will get inside of a prune cluster is really astonishing. Many times the writers have, from a single cluster, taken more than a hundred of these little insects feeding upon the tender blossom stems, the tips of the petals, and the stigma and style of the blossoms when they have opened. These parts mentioned seem to be the choice bits for the adults when feeding upon the prunes. The rapidity with which the thrips can destroy the whole year's crop is astonishing. Many a time orchardists have gone into their prune orchards at the time the buds were about ready to spread, and, with only casual observation, have failed to see these minute, dark-colored insects crawling around or at rest upon the twigs and buds. Upon inspecting the orchard four or five days later, expecting it to be in full bloom, they have been astounded to find practically all the buds destroyed, leaving no hope for a crop that year, the entire orchard presenting a brown, burnt appearance, with only a stray blossom now and then, a sight which is well known now to the majority of the prune growers of the Santa Clara Valley. Anyone who has ever seen one of these prune orchards with the burned, browned, and blasted appearance beside another of snowy whiteness will never forget the contrast. (See Pl. IV, comparing fig. 1 with fig. 2.) Again there may be a very severe larval injury on prunes, such as was the case in 1911. Very few adult thrips occurred in comparison with

FIG. 1.—UNTREATED PORTION OF PEAR ORCHARD, SHOWING LOSS OF PEAR BLOSSOMS RESULTING FROM ATTACK OF THE PEAR THRIPS. (ORIGINAL.)

FIG. 2.—SPRAYED PORTION OF SAME ORCHARD, SHOWING TREES IN BLOSSOM. (ORIGINAL.)

INJURY TO PEAR ORCHARDS BY THE PEAR THRIPS.

FIG. 1.—UNSPRAYED PORTION OF PRUNE ORCHARD IN WHICH BLOSSOMS ARE COMPLETELY DESTROYED BY THE PEAR THRIPS. (ORIGINAL.)

FIG. 2.—SPRAYED PORTION OF THE SAME ORCHARD, SHOWING TREES IN FULL BLOSSOM. (ORIGINAL.)

INJURY TO PRUNE ORCHARD BY THE PEAR THRIPS.

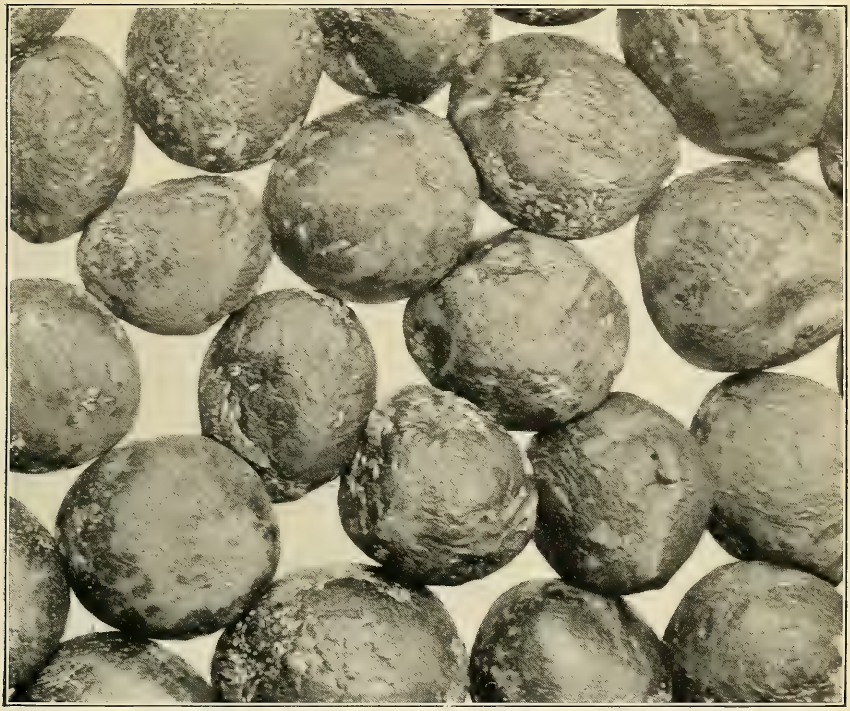


FIG. 1.—PRUNES SCABBED AS A RESULT OF FEEDING BY PEAR THRIPS LARVÆ. (ORIGINAL)

FIG. 2.—NORMAL FRUIT, UNINJURED BY THE PEAR THRIPS. (ORIGINAL.)

PRUNES INJURED AND UNINJURED BY PEAR THRIPS LARVÆ.

1910, and they did not accomplish much injury in the Santa Clara Valley, but larvæ were present in large numbers everywhere and riddled the foliage (fig. 4) and weakened the fruit stems, making the financial loss amount to about half as much as in 1910.

In regard to varieties, Imperial prunes seem to be attacked first and injured, on the whole, more severely than French prunes in the Santa Clara Valley. This may be explained in several ways: For one thing, the acreage of this variety in the Santa Clara Valley is much less than that of the French prunes and the blossoming period is usually about a week or more earlier; then, too, the small develop-

Fig. 4.—Prune foliage riddled by pear thrips larvæ. (Original.)

ing fruit stems of the Imperial prunes seem to be more tender and not so able to withstand the attacks of the thrips as are those of the French prunes. Sugar prunes, which blossom at a period intermediate between the blossoming periods of Imperial and French prunes, are, from a financial standpoint, not injured so greatly as are either of the other varieties. This is partly due to the fact that this variety sets an unusually large amount of fruit and is therefore able to withstand the loss of a considerable portion of it and still produce a fair crop. The scabbing of the prunes on this variety, however, is often so deep as to cause a large exudation of gum and to render a large

portion of the fruit unmarketable. Plate V, figures 1 and 2, shows photographs of sprayed and unsprayed prunes, the prunes having been picked from trees when full grown. Robe de Sargent prunes blossom about the same time as French prunes, and are injured to the same extent as that variety.

INJURY TO CHERRIES.

Cherries, as a whole, are not injured so severely by the feeding of a given number of adults as would be the case for the same number of thrips upon pears and prunes, but certain varieties, especially the black cherries, suffer comparatively as much from a monetary standpoint as either pears or prunes. Probably the worst damage accomplished on cherries is by the deposition of eggs in the long fruit stems and in the leaves, and by the feeding of the larvæ upon the foliage. The deposition of eggs in the fruit stems has at times caused a large percentage of the cherry crop to drop, and it is a common sight to see the foliage entirely riddled by the larvæ, thus greatly weakening the trees. Many other instances are on record where the adults have injured the fruit buds to such an extent that only a few blossoms appeared. Late varieties of cherries, such as the Royal Anne, escape serious injury more than the earlier blooming black varieties. Fortunately the manner of bud growth and blossoming of cherries permits effective penetration of different spray solutions more advantageously than is the case with either pears or prunes.

INJURY TO APPLES.

While there are not many instances of great commercial injury to apples, yet individual cases have been known where the adult thrips have killed all of the buds in the cluster except the central one. This was especially noticeable in an orchard of the Newtown Pippin variety in the vicinity of San Jose in 1910. Some small orchards in Sacramento County were rather seriously injured during the same year.

INJURY TO PEACHES.

Following the apple, peaches come next in importance as regards possibility of dangerous injury, the early varieties suffering the greater loss. The more seriously injured varieties are the Muir, Nicol-cling, Crawford, Foster, and Lovel, in order of damage done, injury being more severe on the first two varieties mentioned. On account of the hairy pubescence on the young peach fruits, the thrips prefer to feed upon the nectary glands and the inside of the calyx cups; this prevents proper pollination, and the young fruits drop to the ground a few weeks after the blossoming period. Where the injury has been severe, peaches are sometimes prevented from blooming, and the larvæ feeding upon the tender leaves cause them to curl and become dis-

torted somewhat in the same manner as does peach leaf-curl. Sometimes the larvæ feed on the young fruit, but rarely to the extent of causing any great loss.

INJURY TO APRICOTS.

Apricots have not, as a rule, been injured commercially except in cases where there are a few young trees around home grounds or near an infested pear or prune orchard. They are sometimes injured to about the same degree as peaches, and in some cases isolated trees have been observed which failed to bloom as a result of the work of the thrips. Larval injury to the young fruit is usually more extensive than is the case with peaches and may at times be serious. However, apricots are apparently not favorite breeding places for thrips.

INJURY TO ALMONDS.

Almonds are injured less by the thrips than any of the foregoing fruits. On account of the early blossoming of the trees and the relatively greater amount of exposed leaf surface at the time the thrips are out in numbers, together with the character of the blossom, which is similar to that of the peach, feeding by the thrips very rarely causes much commercial loss in almond orchards.

DESCRIPTION.

EGG.

The egg when first deposited is bean-shaped, translucent white, measuring on the average about 0.416 mm. in length and about 0.166 mm. at its widest part in the middle. (Pl. I, fig. 2.)

Just before hatching it decreases in length, appears swollen, has a slight brownish tint, and is faintly striated longitudinally where the antennæ and legs are folded together. The dark brown spots, the eyes of the young larva, are apparent at one end.

LARVA.

FIRST STAGE (LARVA 1 DAY OLD).

Length 0.646 mm.; width of head 0.166 mm.; width of mesothorax 0.183 mm.; width of abdomen 0.15 mm.; length of antennæ 0.2 mm.; length of antennal segments: I 20μ, II 40μ, III 45μ, IV 100μ. General color translucent white. General shape fusiform. Antennæ, head, and legs large in proportion to the rest of the body, and unwieldy. Antennæ distinctly four-segmented, first segment short, cylindrical; second segment about twice as long as first, oval cylindrical; third segment slightly longer than second, urn-shaped; fourth about as long as rest of joints together, acutely conical. A few very fine inconspicuous hairs present on all joints, more prominent on segment 4; Head subquadrate; eyes reddish brown. Thorax about as long as abdomen, slightly wider. Abdomen gradually tapering, 10-segmented, first eight segments subequal, IX and X longer and more abruptly tapering, with a fringe of long, white, nearly inconspicuous hairs. Legs stout; femora and tibiæ nearly equal in length; tarsi one-jointed, ending in a single black claw. (Pl. I, fig. 3.)

SECOND STAGE (FULL-GROWN LARVA).

Total length 1.833 mm.; length of head 0.15 mm., width 0.1083 mm.; length of prothorax 0.1833 mm., width 0.2166 mm.; length of mesothorax 0.1833 mm., width 0.466 mm. Length of antennæ 0.2833 mm.; segment I 26μ, II 50μ, III 76μ, IV 66μ, V 14μ, VI 16μ, VII 33μ. Antennæ: Segment I short cylindrical; II obtuse spindle-shaped; III spindle-shaped, about as long as I and II together; IV nearly as long as III, broader than the rest, subconical; V short, narrow cylindrical; VI slightly narrower and longer than V; VII twice as long as VI, narrower and cylindrical. All joints transversely striated and with a few inconspicuous white hairs. General color faintly yellowish white, obtusely fusiform in shape. Body longitudinally and laterally faintly striated. Head quadrate; eyes prominent, dark reddish brown, situated a little in advance of the middle; mouth cone broadly rounded, nearly as long as the head, extending to the middle of the prosternum. Prothorax large, slightly wider than long, diverging posteriorly. Mesothorax and metathorax short and broad, twice as wide as long, subequal, in length about as long as prothorax. Abdomen broad, gently rounded, 10-segmented, broadest at segments V and VI; first eight segments subequal; segment IX distinctly longer, tapering to apex, the posterior edge armed with a circle of strong, short, thick wedge-shaped spines, the two mediodorsal and medioventral ones shorter and smaller; segment X slightly tapering, not quite as long as segment IX. Lateral edges of abdomen finely serrated, also with a few long inconspicuous white hairs which are more prominent on segment X. Legs strong; femora and tibiæ about equal; tarsi one-jointed, ending in a single black claw. (Pl. I, fig. 4.)

NUMBER OF MOLTS; DEVELOPMENT.

When first hatched the larvæ are active and start feeding immediately and soon become more robust. At the end of about seven to eight days they molt into second-stage larvæ, where (see description) they are still more robust and show also other differences. The total time required for the development of the larvæ is about three weeks, although this period is shorter during warm weather.

PUPA.

PREPUPA (FIRST STAGE).

Total length 1.333 mm.; length of head 0.1 mm., width 0.116 mm.; length of prothorax 0.183 mm., width 0.266 mm.; width of mesothorax 0.35 mm.; length of abdomen 0.666 mm., width 0.383 mm. Shape similar to adult; color translucent white, deeply tinted with brown. Head subquadrate, about as broad as long, eyes dark reddish brown. Mouth-cone broadly rounded, extending to about one-half length of the prosternum. Antennæ extending backward on each side of head, apparently four-jointed; first three segments nearly subequal in length, about as broad as long, thick and unwieldy; segment IV about as long as remaining joints, clublike, and tapering to an obtuse point. Antennæ with a few inconspicuous white hairs. Prothorax nearly twice as long as the head, broadly rounded posteriorly. Mesothorax broader; wing pads short, those of first pair of wings extending to distal edge of third abdominal segment. Abdomen 10-segmented, widest at III and IV, segments gradually tapering from there posteriorly. First eight segments subequal, IX and X longer, distal end of IX with broad spines somewhat similar to those of second-stage larvæ but shorter and smaller. Legs stout, similar to those of full-grown larva, whole body with sparse, light-colored, inconspicuous hairs. (Pl. I, fig. 5.)

PUPA (SECOND STAGE).

Total length 1.416 mm.; length of head 0.183 mm., width, 0.166 mm.; length of prothorax 0.166 mm., width 0.25 mm.; width of mesothorax 0.35 mm.; length of abdomen 0.783 mm., width 0.416 mm. Shape similar to adult, which is visible beneath the thin transparent shell. Apparently brownish in color, caused by adult within. Head broader than long; eyes large, dark brown; mouth-cone of adult within extending to posterior edge of prothorax. Antennæ large, cumbersome, laid back on the head and extending past middle of prothorax, four-jointed; I short; II elbowed, about twice as long as I; III short, cylindrical; IV longer than III, sides uneven as knotted club gently tapering to obtuse apex. Joint I of adult is in joint I of pupa, joint II of adult in joint II of pupa, and III of adult within III of pupa; remaining joints of adult within IV of pupa; 3 or 4 white, inconspicuous hairs projecting cephalad from elbow on joint II. Prothorax broader than long. Mesothorax about one and one-half times as broad as prothorax. Wing-pads extending to distal margin of eighth abdominal segment, fore pair not quite so far. Abdomen widest at third and fourth segments, tapering from there to obtuse apex. Posterior edge on ventral side of segment IX with four strong spines resembling a meat fork. This is apparently the cremaster. Legs stout. Entire body with numerous inconspicuous white hairs. (Pl. I, fig. 6.)

ADULT.

Length of head 0.13 mm., width 0.15 mm.; length of prothorax 0.13 mm., width 0.2 mm.; width of mesothorax 0.28 mm.; width of abdomen 0.31 mm.; total length 1.26 mm. Length of antennal segments: I 33μ, II 45μ, III 63μ, IV 54μ, V 33μ, VI 66μ, VII 9μ, VIII 12μ, total 0.31 mm. Color dark brown; tarsi light brown to yellow. Head slightly wider than long, cheeks arched, anterior margin angular, back of head transversely striate and bearing a few minute spines and a pair of very long prominent spines between posterior ocelli. Eyes prominent, oval in outline, black with light borders, coarsely faceted and pilose. Ocelli approximate, yellow, margined inwardly with orange-brown crescents, the posterior ones approximate to, but not contiguous with, light inner borders of eyes. Mouth-cone pointed, tipped with black; maxillary palpi three-segmented; labial palpi two-segmented, basal segment very short. Antennæ eight-segmented, about two and one-half times as long as head, uniform brown except segment III, which is light brown; spines pale; a forked sense-cone on dorsal side of segment III, with a similar one on ventral side of segment IV. Prothorax about as long but wider than head; a weak spine at each anterior and two large, strong ones on each posterior angle; other spines not conspicuous. Mesothorax with sides evenly convex, angles rounded; metanotal plate with four spines near front edge, inner pair largest. The mesonotal and metanotal plates are faintly striate. Legs moderately long, uniform brown except tibiæ and tarsi, which are yellow. Spines on tip of fore and middle tibiæ weak; several strong spines on hind tibiæ. Wings present, extending beyond tip of abdomen, about twelve times as long as wide, pointed at tips; costa of forewings thickly set with from 29 to 33 quite long spines; fore vein with 12 to 15 arranged in two groups of 3 and 6, respectively, on basal half of wing and a few scattering ones on distal part; hind vein with 15 or 16 regularly placed spines; costal fringe on fore wing about twice as long as costal spines. Abdomen subovate, tapering abruptly toward the tip from the eighth segment; longest spines on segments 9 and 10; abdomen uniform brown, connective tissue yellow. (Pl. I, fig. 1.)

SYSTEMATIC POSITION.

The pear thrips belongs to that suborder of the Thysanoptera called Terebrantia, which differs from the other suborder, the Tubulifera, in the possession by the female of a sawlike ovipositor; also, the terminal segments of the abdomen are conical and the wings are not equal in structure, the fore pair being the stronger. The membrane of the wings, also, has microscopic hairs. This species is placed in the family Thripidæ and is separated from the Æolothripidæ in that the antennæ usually have from 6 to 8 segments, the wings usually are narrow and pointed at the tips, and the ovipositor is downcurved. It is placed in the genus Tæniothrips of this family because the body is free from reticulation and the abdomen not closely pubescent; the head nearly or quite as long as wide, with a pair of long bristles between the anterior and posterior ocelli; the cheeks swollen, curving abruptly to the strongly protruding eyes; the antennæ eight-segmented, with the last two segments (the style) shorter than the sixth; the maxillary palpi three-segmented, the prothorax very slightly, if at all, shorter than the head, with two long bristles at each posterior angle; the fore tibiæ unarmed; the bristles on the veins of the forewings not equidistant, and the last abdominal segment of the female conical and without a pair of short, stout bristles on the dorsal surface.

Until recently this species was placed in the genus Euthrips Targioni-Tozzetti, which most American authors had used in the sense of Physothrips and Odontothrips, Tæniothrips and Frankliniella. Hood [1] has recently shown that the name Euthrips Targioni-Tozzetti (1881) was first used in a subgeneric sense as a substitute for the name Thrips, which had been used for a subgenus of Thrips Linné (1758), and that it is consequently a synonym of that genus. The pear thrips he places in the genus Tæniothrips Amyot and Serville, the orange thrips in Scirtothrips Shull, and, partly following Karny,[2] the various other species formerly assigned to Euthrips in the genera Physothrips, Odontothrips, and Frankliniella.

ANATOMY.[3]

OVIPOSITOR.

The ovipositor is attached to the ventral side of the eighth and ninth abdominal segments and is composed of four distinct plates, the under pair attached to the eighth segment and the upper or posterior pair to the ninth abdominal segment. The ovipositor in

[1] Hood, J. Douglas. On the proper generic names for certain Thysanoptera of economic importance. *In* Proc. Ent. Soc. Wash., v. 14, no. 1, p. 34–44, 1914.

[2] Karny, H. Revision der von Serville aufgestellten Thysanoptera Genera. *In* Zoologische Annalen, Bd. 4, Heft 4, p. 322–344, 1912.

[3] For a description of the mouthparts see discussion under "Manner of feeding and type of mouthparts," p. 11–13.

the pear thrips is curved downward. The passageway between the plates is grooved so that the eggs can pass through readily. The upper edge (of the upper plates) is fitted with sharp sawlike teeth, while the lower plates have similar teeth for most of the way but also bear a number of broad cutting teeth. The end of the ovipositor is sharp and pointed. When this is inserted into the plant tissues, the slit or opening is enlarged by the action of the hard serrate edges of the ovipositor as it is worked up and down by the rather powerful muscles of the abdomen. The ovipositor when not in use is protected in a sheath along the ventral side of the last two segments of the abdomen.

WINGS.

The wings are long and slender, membranous, with a fringe of fine hair upon both the anterior and posterior margins, and are never folded. Both pairs of wings are quite similar and when at rest are laid back flat upon the abdomen, the pairs lying parallel in the Terebrantia. The wings of the family Thripidæ, to which the pear thrips belongs, are slender, and taper from the base to the tip, which is pointed; they bear a general resemblance to sabers. The veins in the family Thripidæ are not so prominent as in the family Æolothripidæ, and only one or two longitudinal veins are present, the cross-veins being very obscure.

FEET.

The legs and feet of thrips form one of the chief characteristics which separate this order from the various other orders of insects. They are composed of the usual parts of an insect leg, namely, coxa, trochanter, femur, tibia, and tarsus. There is nothing unusual in the formation of the first four parts, the femur and tibia usually being quite long and somewhat cylindrical. The tarsus is the most peculiar structure on the leg, and may be either simple or of two segments, and usually ends in one or two claws. In the family Thripidæ, they belong to the former type. The remarkable bladder-like structure, which for many years gave the name Physopoda to this order, is protrusile from the end of the last tarsal segment. It is present in both adults and larvæ. The end of the tarsus is cup-shaped, and into this cup the delicate membranous bladder is attached. When the foot is at rest the bladder is invisible and is withdrawn into the end segment. The bladder is protruded and brought into action when the adult is resting on some surface or walking around. The mechanism of the bladder has been partially worked out by Jordon and Uzel, but as it is somewhat intricate it will not be described here. If a swollen bladder is pricked or ruptured, the blood pours out and the bladder collapses quickly. The

blood is probably what causes the protrusion of the bladder. Various agencies have been used in experiments to hinder the thrips in walking about on the surfaces of the plants they are attacking, with the view that if in some way the mechanism of the bladder was affected, either by causticity or by absorption, the bladder would not be able to perform its function, and the insects would fall from any surfaces that were so treated. This has not been successful from the writers' experience, as they have observed on numerous instances thrips crawling around on sticky surfaces, even on tanglefoot, which was to all appearances and to the touch very sticky. This bladderlike formation is probably so delicate that surfaces which appear smooth or sticky or caustic to the naked eye and human touch are rough and uneven to the thrips and are neither adhesive nor caustic. The writers have never seen thrips stuck to any surface by the ends of their tarsi, but only by their bodies, legs, or wings. It is apparent that they are able to walk on practically every kind of surface, especially after this treated surface has been exposed to the atmosphere for a few hours.

LIFE HISTORY AND HABITS.

ADULTS IN SPRING.

EMERGENCE FROM GROUND.

The first form of the pear thrips to be seen by the orchardists during the growing season is the adult (Pl. I, fig. 1), which emerges from the ground during the last winter months and the early spring. The period in which they first appear upon the trees in Santa Clara, Contra Costa, Solano, and Sacramento Counties is variable. Certain sections in each territory are earlier than others and some orchards are in advance of others in regard to blossoming conditions.

In the Santa Clara Valley during the year 1909 the first adult thrips were collected February 15. (See Table IV.) By February 18 they were quite numerous in one of the orchards under observation and were common in all orchards by February 25. Maximum emergence began about February 19 and lasted until March 18. They continued to emerge until the first three days in April. In Contra Costa County first thrips were out at the laboratory February 12 and in the field February 16, emerging in numbers by February 20. Maximum emergence was over by March 15 and all were out by March 27. During the season of 1910 the first thrips taken in the field in Santa Clara County were observed on February 7, while the first in emergence cages appeared on February 9. They were common in the field from February 15 on. Thrips appeared in maximum numbers from the cages (see fig. 5) beginning February 22 and ending March 10, with the last stragglers coming out as late as March 20. The emergence season for 1911 at first gave promise

of being very early, as the first thrips were found in the field on January 29 and in the emergence cages February 1; but the heavy rains following in February and March caused it to be very backward, so that thrips were not common in the field until March 14, which was about the time of the true maximum emergence.

In Contra Costa County during the season of 1909 the maximum number of thrips emerged in cages, which were put in the ground in the yard at the laboratory, from February 23 to March 4. (See

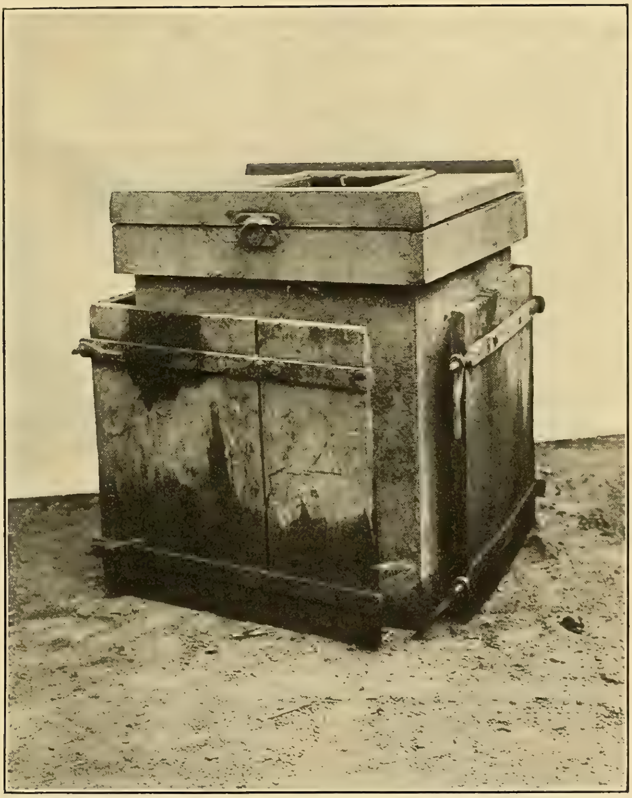


FIG. 5.—Type of soil cage used for soil samples in obtaining emergence records of the pear thrips at San Jose, Cal. (Original.)

Table VI and fig. 7.) In cages placed under trees (see fig. 6) in the field the thrips emerged in maximum numbers from February 26 to March 12 (see Table V and fig. 8). During the spring of 1910 the first thrips found to emerge in the cages at the laboratory were out on February 18 (see Table VI and fig. 9) and in the field cages on February 21, reaching a greater daily emergence by March 1, and continuing to emerge in considerable numbers until March 15, the maximum emergence being March 7 (see Table V and fig. 10). By comparing figures 7 and 8, which show the emergence records for

1909, with figures 9 and 10, showing the record for 1910, it will be seen that the time of emergence in any considerable numbers was much shorter in 1910 than was the case in 1909. No actual daily emergence records were kept in 1911, but no thrips were found in the field until February 18 and then only very few in one early almond orchard. On February 24 a few scattering specimens were found in two pear orchards. Not until March 12 were they appearing in any noticeable numbers, but the emergence was very rapid after this, reaching the maximum between March 15 and 20. The emergence of adults was mostly over by March 30.

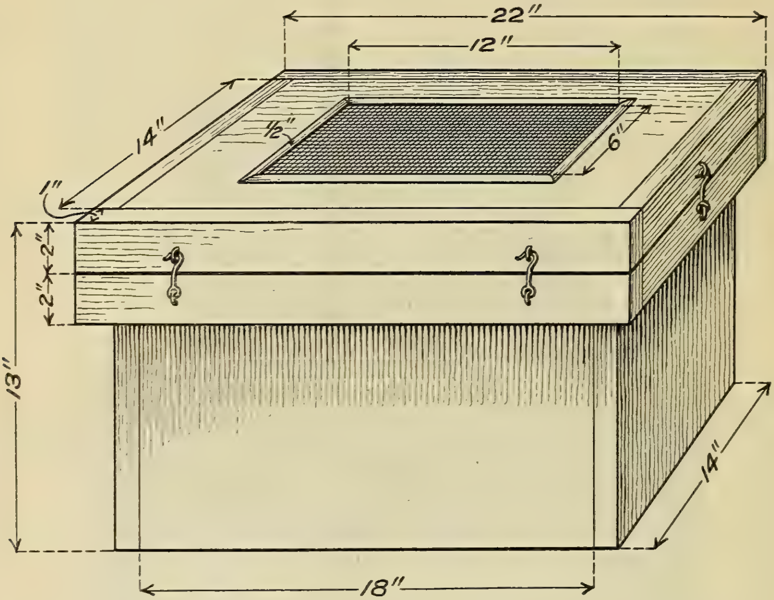


FIG. 6.—Type of wooden cage used for field emergence records of the pear thrips in orchards at Walnut Creek, Suisun, and Courtland, Cal., 1909–10. (Original.)

Emergence records and field observations in the Suisun Valley of Solano County (see Table VII and fig. 11) show that for the season of 1910 thrips came out of the ground in numbers on about the same dates as for Contra Costa County. They were out in numbers in the Courtland district of Sacramento County from two to four days earlier. Further observations in 1911 showed the emergence in these two sections to be about the same time as for Contra Costa County.

Records of the emergence for the years 1909, 1910, and 1911 are summarized in Table IV. From this table it will be seen that in Santa Clara County in 1909 most thrips appeared on March 3 while in 1910 March 4 yielded the highest number, with March 3 and 2

following close behind. The increase in emergence during the season 1909 (fig. 12) and the tapering off in the same year was more gradual

FIG. 7.—Curve illustrating emergence of adult pear thrips at laboratory, Walnut Creek, Cal., 1909. (Original.)

than during the season 1910 (fig. 13). This difference was most probably influenced during the latter season by the temperature.

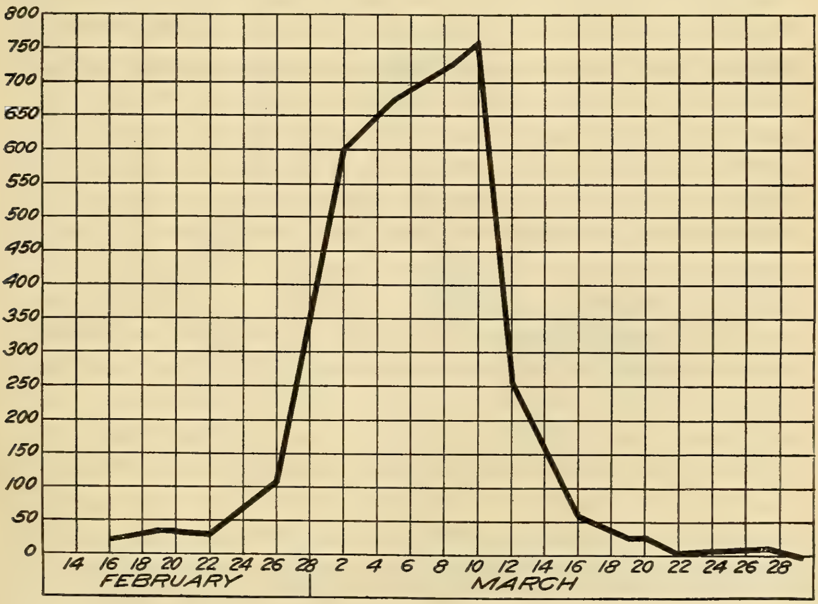


FIG. 8.—Curve showing emergence of pear thrips in cages under trees in field at Walnut Creek, Cal., 1909. (Original.)

RELATION OF EMERGENCE TO TEMPERATURE AND RAINFALL.

The average mean temperature for February and March, 1911, or the two months when practically all of the thrips emerged, was

50.7° F., or about the same as in 1909, and the emergence probably would have been very similar to the emergence for that year but for the abnormal precipitation in February and March, especially in the latter month.

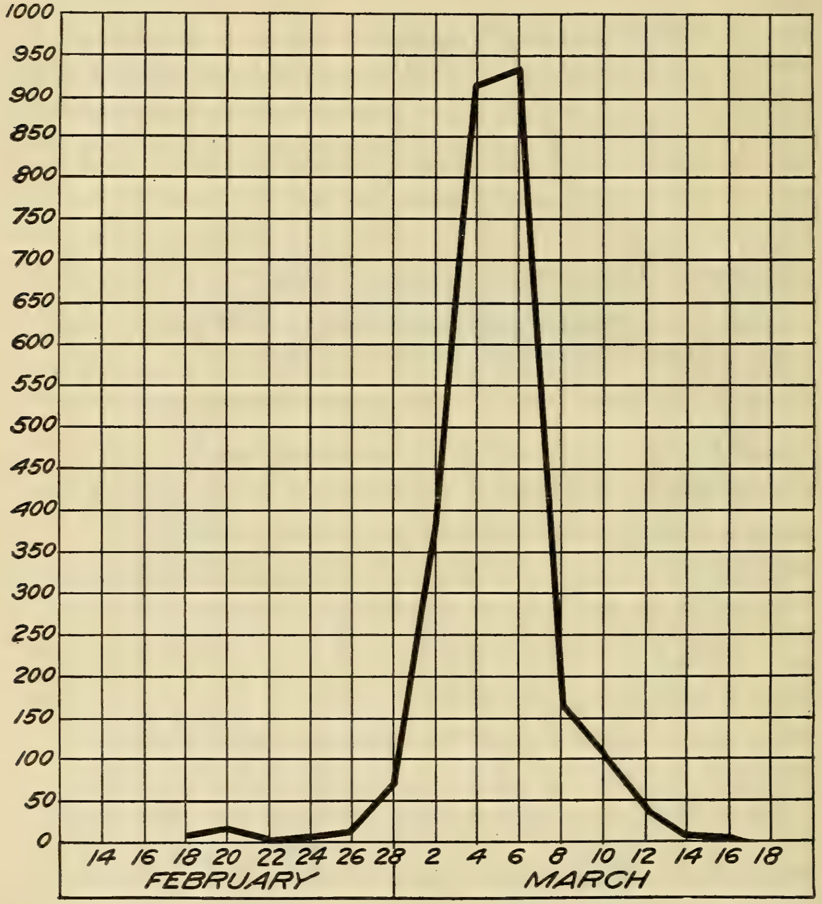


FIG. 9.—Curve showing emergence of adult thrips at laboratory, Walnut Creek, Cal., 1909. (Original.)

TABLE II.—*Mean temperatures for the months of February and March, 1909, 1910, and 1911.*

	°F.
Mean maximum temperature for month of February, 1909	59.2
Mean minimum temperature for month of February, 1909	42.2
Average mean temperature for month of February, 1909	51.0
Mean maximum temperature for month of March, 1909	60.0
Mean minimum temperature for month of March, 1909	40.0
Average mean temperature for month of March, 1909	50.0
Mean maximum temperature for month of February, 1910	58.8
Mean minimum temperature for month of February, 1910	38.5

	°F.
Average mean temperature for month of February, 1910	49.0
Mean maximum temperature for month of March, 1910	66.2
Mean minimum temperature for month of March, 1910	44.5
Average mean temperature for month of March, 1910	55.0
Mean maximum temperature for month of February, 1911	56.5
Mean minimum temperature for month of February, 1911	37.3
Average mean temperature for month of February, 1911	46.9
Mean maximum temperature for month of March, 1911	63.3
Mean minimum temperature for month of March, 1911	46.0
Average mean temperature for month of March, 1911	54.6

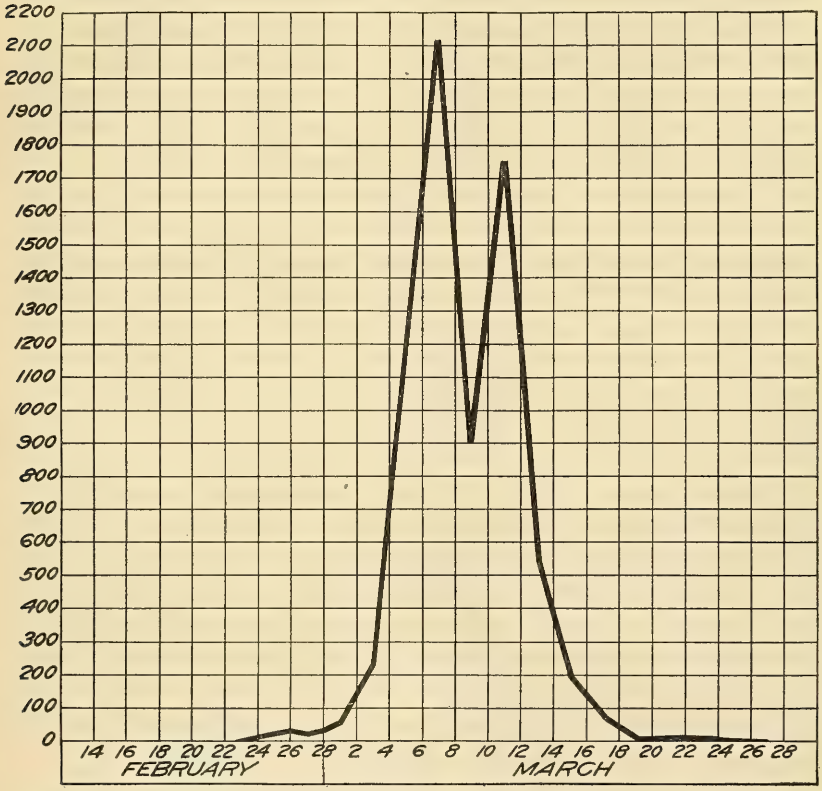


FIG. 10.—Curve showing emergence of adult pear thrips in cages under trees in field, at Walnut Creek, Cal., 1910. (Original.)

It will be seen from the temperature records (Table II) that while February, 1909, had 2 degrees higher average mean temperature than February of 1910, March of 1909 had 5 degrees less average mean temperature than March of 1910, making the average mean temperature for the months in which most of the adults emerged 50.5° F. in the year 1909 and 52° F. in the year 1910. Another factor which held back the emergence greatly the former year was the

greater rainfall, the month of February, 1909, having 4.87 inches precipitation while February of 1910 had only 0.83 of an inch.

A comparison of the amount of precipitation for the three years 1909, 1910, and 1911 (see Table III) shows a large amount for 1909,

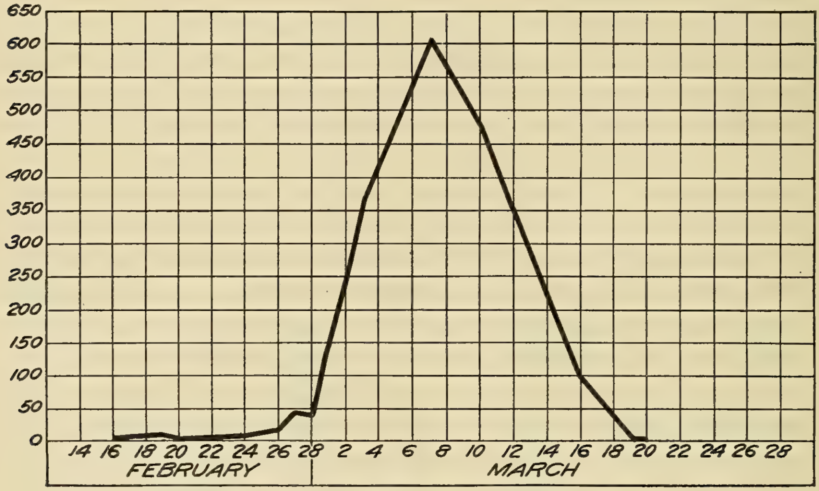


FIG. 11.—Curve showing emergence of pear thrips at Suisun, Cal., 1910. (Original.)

which with the low average mean temperature for the two emergence months caused the emergence to be drawn out. The season 1911 was very abnormal in the large amount of precipitation, especially

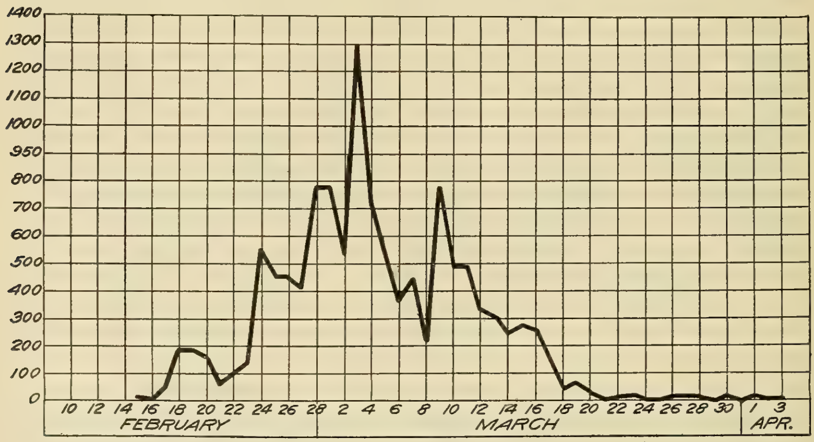


FIG. 12.—Curve showing emergence of pear thrips at San Jose, Cal., 1909. (Original.)

during the latter part of February and early March, causing a late blossoming season, and holding the thrips back to such an extent that comparatively little injury was caused by the adults.

TABLE III.—*Total precipitation for the years 1909, 1910, and 1911 at San Jose, Cal., laboratory.*

Month.	Precipitation in inches.		
	1909	1910	1911
February	4.87	0.83	2.03
March	2.77	2.84	6.26

One curious fact about the emergence for 1911 was the double maximum, one the latter part of February, from the 18th to the 26th, and another from the 8th to the 15th of March. (See Table IV and

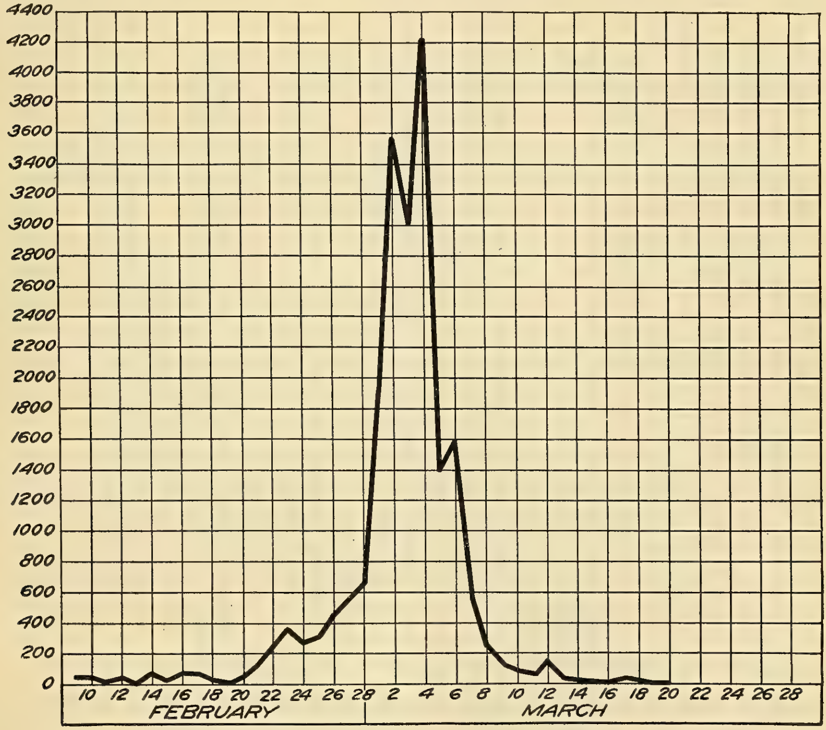


FIG. 13.—Curve showing emergence of pear thrips at San Jose, Cal., 1910. (Original.)

fig. 14.) From February 26 to March 11, inclusive, it rained every day from 0.02 of an inch to as much as 2.45 inches. Probably a number of the thrips which emerged in February were killed by the heavy rains in early March, or at least were not permitted to cause much injury. The pear thrips emerges from the ground during rainy weather, but not in such great numbers as during warm, sunshiny days, which was the case during the latter part of February and the early part of March of the year 1910. Whether the soil is clean or covered with weeds and grass at this time of year influences the time

of emergence by some two or three days. This was particularly noticeable in pear orchards used in cultivation experiments in Contra Costa and Solano Counties. In the plowed portions which were free from weeds, the surface dried out and warmed up more rapidly and thrips came out in numbers and into the trees three days earlier than on the unplowed part of the orchard, which was covered with a rank growth of vegetation. The shading of the soil by the vegetation seems to result in holding the thrips within the ground several days later, or else they spend some time on this succulent growth before going into the trees.

The following tables give the emergence records for the years 1909, 1910, 1911, and 1912 for Santa Clara County (San Jose, Table IV);

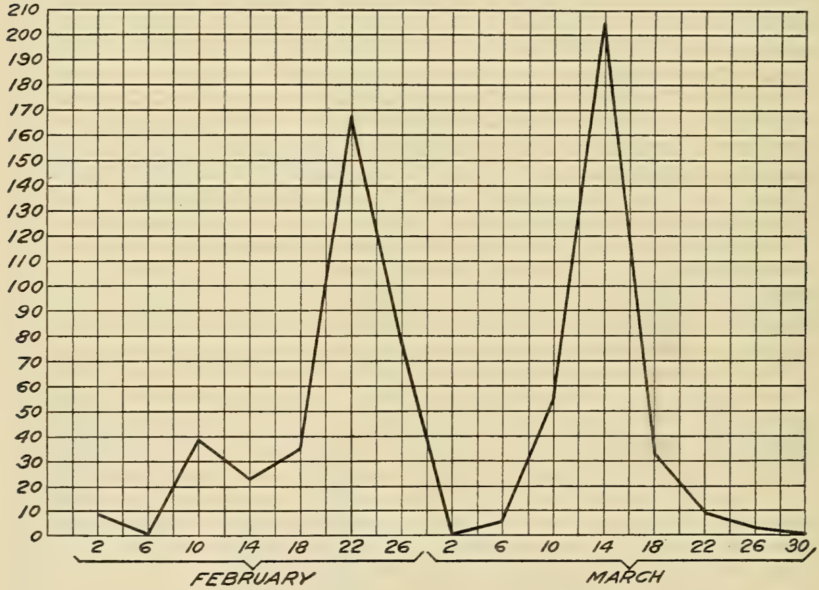


FIG. 14.—Curve showing emergence of pear thrips at San Jose, Cal., 1911. (Original.)

for 1909 and 1910 in Contra Costa County (Walnut Creek, Tables V and VI), and for 1910 in Solano County (Suisun, Table VII). These tables show the total number of thrips emerging on the given dates from soil in the cages. For the San Jose records, all the cages containing soil samples from infested prune orchards were placed in the ground at the laboratory. For the records in Contra Costa and Solano Counties, part of the cages were brought to the laboratory and buried in the ground and part were left in the ground under the trees in infested orchards. (See fig. 6 for type of cage used for the field emergence records in the northern counties.) It was not possible to take the emergence every day, but, so far as possible, counts were made at regular intervals.

TABLE IV.—*Total emergence of pear thrips from all the cages kept at the laboratory at San Jose, Santa Clara County, Cal., during 1909, 1910, 1911, and 1912.*

Date	Number of thrips emerging in 1909 from 18 cages.	Number of thrips emerging in 1910 from 18 cages.	Number of thrips emerging in 1911 from 4 cages.	Number of thrips emerging in 1912 from 4 cages.	Date.	Number of thrips emerging in 1909 from 18 cages.	Number of thrips emerging in 1910 from 18 cages.	Number of thrips emerging in 1911 from 4 cages.	Number of thrips emerging in 1912 from 4 cages.
Feb. 1	0	0	2	1	Mar. 9	776	144	1	366
2	0	0	7	1	10	497	100	32	442
3	0	0	0	0	11	498	73	54	81
4	0	0	0	0	12	338	179	71	83
5	0	0	0	1	13	313	45	56	161
6	0	0	1	5	14	248	20	22	313
7	0	0	28	3	15	279	7	17	433
8	0	0	5	6	16	259	4	9	239
9	0	25	1	9	17	152	20	2	158
10	0	18	4	9	18	42	7	4	596
11	0	16	1	9	19	61	2	0	209
12	0	16	22	21	20	28	2	0	144
13	0	4	0	15	21	2	0	3	106
14	0	88	0	33	22	6	0	6	114
15	18	22	11	37	23	13	0	1	103
16	0	27	5	65	24	3	0	1	68
17	52	34	2	104	25	2	0	0	52
18	192	33	17	242	26	3	0	1	39
19	192	14	62	490	27	7	0	1	38
20	169	23	41	384	28	7	0	0	61
21	75	62	32	325	29	0	0	0	17
22	119	129	33	440	30	2	0	0	14
23	135	375	25	422	31	0	0	0	14
24	552	272	26	515	Apr. 1	3	0	0	28
25	459	297	18	800	2	0	0	0	19
26	444	455	8	504	3	1	0	0	9
27	414	574	0	762	4	0	0	0	7
28	781	657	0	1,694	5	0	0	0	4
29	....	....	....	1,169	6	0	0	0	4
Mar. 1	781	1,975	0	1,721	7	0	0	0	26
2	535	3,592	0	276	8	0	0	0	5
3	1,299	3,011	2	284	9	0	0	0	3
4	714	4,217	4	399	10	0	0	0	1
5	508	1,402	0	400	11	0	0	0	1
6	362	1,595	0	585	12	0	0	0	0
7	438	539	1	1,227					
8	219	275	21	1,052	Total..	11,998	20,350	660	17,968

TABLE V.—*Emergence of pear thrips from cages placed in ground under trees in pear and prune orchards, Walnut Creek, Contra Costa County, Cal.*

Date.	Number of thrips emerging.	Date.	Number of thrips emerging.
1909.		1910.	
Feb. 13	0	Feb. 21	1
16	20	23	4
19	37	25	23
22	30	27	36
26	110	Mar. 1	56
Mar. 2	615	3	237
5	679	5	1,170
10	752	7	2,110
12	273	9	892
16	65	11	1,773
20	33	13	557
22	4	15	198
27	11	17	71
		19	3
		21	6
		27	5

TABLE VI.—*Emergence of pear thrips from soil samples taken from orchards in December and January and kept in cages at laboratory, Walnut Creek, Contra Costa County, Cal.*

Date.	Number of thrips emerging.	Date.	Number of thrips emerging.
1909.		1910.	
Feb. 12	3	Feb. 18	11
15	42	20	16
16	56	22	0
17	38	24	12
18	56	26	30
20	89	28	75
23	125	Mar. 2	377
25	185	4	918
27	246	6	937
Mar. 1	196	8	165
4	237	10	114
7	51	12	47
10	52	14	0
14	13	16	4
19	0		
22	0		

TABLE VII.—*Emergence records of pear thrips for Suisun, Solano County, Cal., 1910.*

Emergence of thrips from cages placed in ground under trees in orchards, Suisun, Cal.		Emergence of thrips from soil samples taken from orchards in December and January and kept in cages at laboratory, Suisun, Cal.	
Date.	Number of thrips emerging.	Date.	Number of thrips emerging.
Feb. 17	3	Feb. 16	1
19	0	17	3
21	0	18	2
23	0	19	6
25	1	20	1
27	20	21	1
Mar. 1	47	22	4
3	121	23	2
10	484	24	5
16	1	25	11
		26	11
		27	14
		28	41
		Mar. 1	105
		2	247
		3	243
		7	612
		12	357
		16	82
		19	8

The latest dates on which adult thrips were collected in the field were about the same for the years 1909 and 1910, the last ones being found from April 15 to April 25. In 1911 living adults were found as late as the middle of May. They were very scarce, however, after May. The number of living adults as a rule decreases rapidly after April 1.

The time adults will feed before they begin ovipositing varies. Those individuals which emerge early and which do not have a suit-

able place for ovipositing will feed from 15 to 20 days before placing any eggs, while individuals which emerge at a later date, as, for instance, from March 5 to 20, do not as a rule feed more than one or two days before depositing eggs. Individuals which were taken from emergence cages and placed in mica chimneys were observed ovipositing the day following their emergence. It is possible that in the field thrips begin depositing eggs more quickly on certain varieties of fruits than on others. This would be governed very largely by the presence or absence of available tissue suitable for oviposition. For this reason on the early blooming varieties of cherries thrips probably feed for a shorter time before oviposition commences than is the case with other fruits.

PERIOD OF EGG LAYING FOR INDIVIDUALS.

The egg-laying period for individuals does not usually last for more than three weeks. Individual thrips confined in mica chimneys on March 5, 1910, did not deposit any eggs after the latter part of March. The full period of egg laying for the entire brood throughout all the infested areas extends from about February 20 until near April 10, or a period of six to seven weeks.

LENGTH OF LIFE OF ADULTS.

Adult thrips confined in vials without food lived on an average three days, while those confined in vials with food lived about two weeks. Adult thrips confined on the trees within mica chimneys lived from three weeks to one month. The length of life of individuals in the field has not been observed accurately, but probably ranges in duration from three weeks to one month and a half.

RELATION OF EMERGENCE TO BLOSSOMING OF TREES.

The emergence period extends from early February to early April and is closely associated with the blossoming periods for the different varieties of fruits. Budding and blossoming of the different fruits is as follows: Almond buds begin to swell during the latter part of January and early February, and this variety of fruit is in full bloom between February 8 and 24. Apricots show first blossoms from February 12 to 23, and most varieties are in full bloom by from March 3 to 10. Peaches show first blossoms about February 23 and many varieties are in full bloom from March 8 to March 17. Black Tartarian cherries reach full bloom by March 15 to 20, while the Royal Anne variety has not at that time opened its buds. French prune buds are beginning to swell between March 8 and 11 and first blossoms appear by March 20. They are usually in full bloom between

March 26 and April 8. The Sugar and Imperial varieties precede the French by about one week. Bartlett pear buds begin to swell the last of February or the first of March, the first clusters usually spreading from March 10 to 15 and are in full bloom for quite an indefinite period between March 20 and April 10. Pears, prunes, and cherries, which are spreading their bud clusters just after the maximum numbers of thrips are coming from the ground, are the fruits most seriously injured by the pear thrips.

MIGRATORY HABITS.

Evidences of the migratory habits of the pear thrips have been noticed at times during the last three or four years. However, no definite observations concerning their migration had been made until the year 1910. Hitherto it had been noted that in some orchards the adults were very numerous early in the season and doing extensive damage. Later observations at an interval of four or five days showed very few adults present, and the entire orchard had the characteristic browned and burnt appearance. It was quite evident that after destroying all the fruit buds the thrips had migrated to other orchards in search of food.

It was possible to obtain more definite knowledge regarding migration in the year 1910 than had heretofore been known, for the reason that the thrips were unusually numerous throughout all the infested areas that year and weather conditions were such that practically the entire brood emerged from the ground in a few days. Also, following their emergence in great numbers, the weather was sufficiently warm that the destruction of the fruit buds in the various orchards was accomplished in much shorter time than is usually the case. Observations so far indicate that thrips migrate in swarms only on bright, warm days. Numerous instances of supposed migration were mentioned to the writers at various times during the season, the reports stating that the pear thrips were flying in swarms, but most of the cases reported lacked authentic evidence to bear them out, such as the saving of specimens. However, in the afternoon of March 28, 1910, the junior author drove out from San Jose toward Saratoga and had great difficulty in keeping both hands on the reins on account of the great numbers of thrips which, flying through the air, filled his eyes and covered his clothes. The prevailing direction of the wind on this day was not observed; no distinct migration or swarm was noted, however, although individuals were numerous flying across the road and could be readily seen when the observer looked toward the sun. They were more numerous on roads running north and south, and extended over a territory of 4 or 5 miles; they were the most numer-

ous at the west end of Hamilton Avenue and along the San Tomas and Santa Clara and Los Gatos Roads.

On March 30, 1910, still more definite information was gained, and this is probably the most unique record of thrips migration which has yet been taken. The day was bright and rather warm and ended with the evening warm and a gentle breeze blowing from the south. Mr. E. L. Fellows, who was in Santa Clara on this day, started home about 5 o'clock in the afternoon. About 5.15 p. m., out on the Saratoga Road, he noticed a number of small, black insects which covered his face and hands, his hat and clothes, and got into his eyes. When he was one-fourth of a mile north of Meridian Corners he met the thickest part of the swarm, which appeared literally like a black, glistening, seething mass moving up and down like heat waves. From this place the insects became less numerous as he went toward home, which he reached about 6 p. m. He thought the swarm to be about 8 miles long and 4 miles wide, from 4 to 15 feet high, moving at the rate of about 10 miles per hour northward toward San Francisco Bay. As he was not sure concerning the identity of this insect, he gathered several hundred specimens in a paper bag and submitted them to the junior author for identification. They were found to be the pear thrips, *Tæniothrips pyri*. This same swarm was noticed by the junior author and by several fruit growers, but they did not have the opportunity to view the whole swarm as did Mr. Fellows.

Continued observations during the season of 1910 showed that the usual time for migration was from 3 to 6 p. m. on bright, warm days during the latter part of the period of maximum oviposition, which was also about the time many orchards have been so badly injured that the trees will not bloom.

This migratory habit is undoubtedly influenced chiefly by a desire for a new supply of food, better places for deposition of eggs, and suitable weather conditions, especially the temperature. The direction in which thrips will migrate depends upon the direction the wind is blowing, and the distance at which suitable feeding places are found.

No distinct migration of the whole brood has ever been observed, such as is the case with some species of Orthoptera. The migration from certain badly infested orchard localities has been influenced, without doubt, by the early destruction of the fruit buds in these orchards. Many instances are known where thrips are numerous and their injury severe in an orchard one year and not very numerous the succeeding year, but they are usually highly injurious again the third year. This phenomenon is more noticeable in pear than in prune orchards, due probably to the fact that a pear

orchard in which all fruit buds have been destroyed is poor feeding ground for both adults and larvæ and reproduction is at the minimum under such conditions. This reappearance in damaging numbers the third year makes it evident that the orchardists should not allow their orchards to go untreated. It should be noted that the years 1907 and 1910 were the only seasons in which the pear thrips migrated to any great extent. No migration was known in the season of 1911, although it was watched for.

MANNER OF REACHING TREE TOPS FROM GROUND.

Most of the adults when emerging probably crawl around for a while on the ground until their wings get sufficiently dry and then fly up into the tree. Some, however, must undoubtedly crawl up the trunk, as a few have been caught by tanglefoot bands. This, however, can not be used as a method of control, since very few go up this way; moreover, the thrips would not be caught unless the bands were renewed every day or so, because the bands do not remain sufficiently sticky after a short exposure to the atmosphere.

REPRODUCTION.

According to Bagnall [1] an example of the male pear thrips was found by him among some specimens of this species taken from plum blossoms at Evesham, England, and submitted to him by Mr. Collinge, director of the Cooper Research Laboratory at Berkhamstead. His only description is that "It is much smaller than the female and the wings considerably overreach the tip of the abdomen." This is the first report of the existence of the male of this species, and in California very extensive observations by the writers and other workers have failed to show a single male, and the only type of reproduction known is by parthenogenesis. In all of the life-history experiments to secure data upon the length of the egg stage individual females were taken directly from the emergence cages and isolated. It is highly probable that practically all of the eggs which are deposited hatch, as no sterile eggs have ever been found.

OVIPOSITION.

Moulton [2] states that he has observed the adult in ovipositing to make first a hole in the epidermis of the plant tissue with the mouth before depositing the egg. Repeated observations by the writers of a large series of adults during oviposition have failed to

[1] Bagnall, Richard S. A contribution to our knowledge of the British Thysanoptera (Terebrantia), with notes on injurious species. *In* Jour. Econ. Biol., v. 4, no. 2, p. 33–41, July 7, 1909. See p. 39.

[2] Moulton, Dudley. The Pear Thrips (*Euthrips pyri* Daniel). U. S. Dept. Agr., Bur. Ent., Bul. 68, pt. 1, rev., p. 7, Sept. 20, 1909.

show a single one going through this procedure. The usual method as shown by observations during the season of 1910 is as follows: The female starts the ovipositor into the tissue by working the abdomen up and down, gradually forcing the ovipositor its full length into the tissue. After this is done the thrips remains quiet for a short interval while the egg is passing out between the plates of the ovipositor. When finished, the female vibrates her antennae and jerks out the ovipositor. The prevailing posture during the whole period of oviposition is with the abdomen arched and the legs spread apart wider than when in walking. The average time required for the operation by a number of individuals observed during the season of 1910 ranged from three to five minutes. After depositing an egg the female usually resumes feeding for a short interval, but some individuals have been observed to deposit two and three eggs in succession without any feeding between times. The number of eggs that a female can deposit in a day is probably not over seven or eight, as the abdominal cavity is not large enough to hold more at one time.

EGGS.

PLACE OF DEPOSITION.

The eggs are always placed in the tenderest portions of the plant tissue, such as exposed blossoms, fruit stems, leaf stems, ribs of the leaves (preferably the midribs), and the leaf edges. Still others are placed in the young fruits. The pear thrips apparently prefers to oviposit upon cherries if a cherry tree is at hand, as the fruit and leaf stems, on account of their length and tenderness, offer excellent places for oviposition without making it necessary for the thrips to move over a large area. However, the small prunes and the stems, as also the stems and midribs of the young leaves of both prunes and pears, are well suited for oviposition by this species. The counts in Table VIII were taken upon leaf stems and fruit stems of French prunes and show the comparative percentage of eggs deposited in each; they also show the inability of the different spray mixtures to kill the eggs within the plant tissues, as these stems in question had been sprayed two days previously with a combination of tobacco extract and distillate emulsion.

Table VIII.—*Comparative percentage of eggs deposited in fruit stems and leaf stems of French prunes, San Jose, Cal., season of 1910.*

No. of observation.	Number of eggs in leaf stems.	Number of eggs in fruit stems.	No. of observation.	Number of eggs in leaf stems.	Number of eggs in fruit stems.
1	2	7	44	1	12
2	1	10	45	0	11
3	5	5	46	7	8
4	0	12	47	3	8
5	2	13	48	7	9
6	1	6	49	5	11
7	3	8	50	2	9
8	0	8	51	12	9
9	0	8	52	10	11
10	1	9	53	2	9
11	1	8	54	3	10
12	2	10	55	7	12
13	2	4	56	0	6
14	5	6	57	9	10
15	3	10	58	5	10
16	2	11	59	12	4
17	0	5	60	5	11
18	3	12	61	0	17
19	3	10	62	6	9
20	1	8	63	2	13
21	0	6	64	4	9
22	0	3	65	5	12
23	3	10	66	8	6
24	1	9	67	0	7
25	1	5	68	11	8
26	2	13	69	8	9
27	1	10	70	5	16
28	1	5	71	9	7
29	1	9	72	3	8
30	2	8	73	2	9
31	0	16	74	2	7
32	2	8	75	9	11
33	2	4	76	17	8
34	1	15	77	6	10
35	0	9	78	11	4
36	0	11	79	12	8
37	1	7	80	9	14
38	4	19	81	8	9
39	7	16	82	2	8
40	2	13	83	1	11
41	5	7	84	0	11
42	3	12			
43	3	9	Total...	299	786

It will be seen from this table that the average number of eggs placed within fruit stems of prunes is more than twice the number placed in the leaf stems. In pears a very large proportion of eggs is placed in ribs and veins of leaves and a comparatively smaller percentage in the fruit stems.

FIRST EGGS.

The first eggs that were noticed in the vicinity of San Jose and in Contra Costa County were placed about March 10 for the season of 1909, while most eggs were being placed about March 15 to 25, and the last eggs in early April. The first eggs were deposited in 1910 in the field about March 9, while maximum oviposition was from March 18 until about April 2. The last eggs were observed to be placed in the field toward the middle of April. In the interior counties, especially Sacramento and Solano Counties, eggs were being deposited in large numbers by March 15, and continued to be deposited in numbers until the latter part of March, a few being found in early April.

LENGTH OF EGG STAGE.

Moulton[1] records the length of the egg stage to be approximately four days, but detailed observations during the season of 1910 at San Jose show it to be considerably longer. The length of the egg stage was first ascertained by inclosing twigs with paper bags before thrips emerged so as to get no outside infestation. Later, when thrips were ovipositing in the field, a considerable number of adults were placed in mica chimneys which had been specially constructed to fit over the twigs in such a manner as to give them as nearly natural conditions as possible, and to permit the eggs to remain in living plant tissue because they usually dried out when the twigs were removed from the tree. These chimneys were made by sewing pieces of strong white cloth in the shape of tubes about 5 or 6 inches long and gluing one end of a cloth tube thus made to each end of the mica chimney. When placed upon the tree, ends of the cloth were tied securely around the twig so that no insects could get in from the outside. The thrips kept for oviposition remained in the cages over night and were removed the next day. To make sure that none would remain in to continue ovipositing, new cages were placed on the twigs in each case. Table IX shows the length of the egg stage.

TABLE IX.—*Length of egg stage of the pear thrips, San Jose, Cal., 1910.*

Cage No.	Date deposited.	Date hatched.	Number of eggs hatched.	Length of egg stage.	Average mean temperature.	Prevailing weather.
				Days.	° *F.*	
I	Mar. 10	Mar. 16	25	6	56	Cloudy.
		17	6	7	57	Do.
		18	9	8	58	Do.
		19	8	9	57	Do.
		20	3	10	57	Do.
		22	10	12	52	Do.
		23	3	13	52	Do.
		24	1	14	52	Do.
II	Mar. 10	Mar. 16	13	6	56	Cloudy.
		17	27	7	57	Do.
		18	30	8	58	Do.
		19	35	9	57	Do.
		20	8	10	57	Do.
III	Mar. 10	Mar. 16	27	6	56	Cloudy.
		17	4	7	57	Do.
		18	9	8	58	Do.
		19	14	9	57	Do.
		20	10	10	57	Do.
		22	4	12	52	Do.
		23	1	13	52	Do.
		24	1	14	52	Do.
IV	Apr. 7	Apr. 14	3	7	55	Clear.
V	Mar. 29	Apr. 5	1	7	56	Clear.
		8	1	10	56	Do.
		10	1	12	56	Do.
VI	Mar. 29	Apr. 7	2	9	56	Clear.
		9	4	11	56	Do.
		10	1	12	56	Do.
		12	1	14	55	Do.

[1] Op. cit., p. 8.

TABLE IX.—*Length of egg stage of the pear thrips, San Jose, Cal., 1910*—Continued.

Cage No.	Date deposited.	Date hatched.	Number of eggs hatched.	Length of egg stage.	Average mean temperature.	Prevailing weather.
				Days.	° *F.*	
VII	Mar. 29	Apr. 3	1	5	56	Clear.
		8	1	10	56	Do.
VIII	Mar. 29	Apr. 7	1	9	56	Clear.
		8	7	10	56	Do.
		9	3	11	56	Do.
		10	4	12	56	Do.
IX	Mar. 29	Apr. 2	1	4	57	Clear.
		6	1	8	56	Do.
		7	1	9	56	Do.
		8	4	10	56	Do.
		10	4	12	56	Do.
		14	1	16	55	Do.
X	Apr. 6	Apr. 12	1	6	54	Cloudy.
XI	Apr. 6	Apr. 13	1	7	54	Cloudy.
XII	Apr. 6	Apr. 13	2	7	54	Cloudy.

SUMMARY.

Number eggs deposited.	Time required for incubation.	Number eggs deposited.	Time required for incubation.
	Days.		*Days.*
1	4	34	10
1	5	7	11
66	6	24	12
44	7	4	13
49	8	4	14
61	9	1	16

For the 296 eggs under observation, the maximum length of the egg stage was 16 days, and the minimum 4 days, making 8.3 days the average time required for incubation.

The eggs of the pear thrips are undoubtedly affected by temperature conditions, but rainy weather as compared with clear weather seems to make no difference when the mean temperature is the same, as all eggs are embedded in the moist plant tissue and do not require additional moisture from the atmosphere.

It is evident that all of the eggs are not in the same stage of development at the time they leave the abdomen of the female, since eggs deposited upon the same day ranged from 4 to 16 days in the length of the egg stage. An examination of the average mean temperature for the various cages shows usually several degrees less mean temperature for a long egg stage in comparison with a short egg stage.

The maximum and minimum temperatures influencing the different lots of eggs are given in Table X.

TABLE X.—*Maximum and minimum temperatures during period of incubation for eggs of the pear thrips, San Jose, Cal., 1910.*

Date.	Maximum temperature.	Minimum temperature.	Date.	Maximum temperature.	Minimum temperature.
	° F.	° F.		° F.	° F.
Mar. 10	73	44	Mar. 28	64	40
11	72	48	29	69	40
12	57	48	30	76	41
13	71	44	31	78	43
14	68	49	Apr. 1	70	45
15	70	44	2	63	43
16	70	53	3	66	46
17	69	54	4	75	41
18	62	50	5	67	46
19	61	48	6	65	46
20	60	51	7	64	40
21	57	47	8	66	45
22	61	46	9	66	47
23	57	39	10	61	51
24	60	37	11	56	47
25	59	44	12	66	46
26	57	44	13	72	41
27	51	42	14	74	41

NUMBER OF EGGS DEPOSITED BY A SINGLE FEMALE.

Up to the season of 1910 only conjectures had been made as to the number of eggs a single female would deposit, but by taking individuals as soon as they emerged and placing them separately upon twigs in the mica cages described under the heading "Length of egg stage," the total progeny of a single female was ascertained—approximately, therefore, the total number of eggs possible for one individual to deposit. Each individual was allowed to remain undisturbed on the twigs inside the cage. After the eggs hatched the larvæ were removed and counted, yielding the following total number: Cage 1, 155 larvæ; cage 2, 146 larvæ; cage 3, 142 larvæ; cage 4, 99 larvæ; cage 5, 117 larvæ. The maximum number of eggs laid is 155, the minimum 99, and the average 131.8. This is probably close to the average number of eggs that would be deposited by a single female out in the field, although some few long-lived individuals would perhaps exceed 200 eggs.

DEPTH EGGS ARE DEPOSITED IN TISSUE.

The eggs are deposited within the plant tissue immediately underneath the outer epidermis and are inclosed by the tissue. The places where they have been deposited can readily be found with the aid of a hand lens because of the little swellings on the stems and by the scars left where the ovipositor had been inserted into the plant.

LARVÆ.

FIRST APPEARANCE.

The very first larvæ appear on almonds, apricots, and the early plums, usually about the 1st of March. Larvæ begin to hatch on prunes and pears the middle of March and usually are in maximum

numbers in the interior valleys of Contra Costa, Sacramento, and Solano Counties the last of March and the first 10 days of April, while the maximum number in Santa Clara County appear the first 15 days of April and the last ones in all the infested regions are found some time in early May.

TIME SPENT IN FEEDING.

The time spent in feeding, or the period required for the larvæ to obtain their growth, is from two to three weeks, for individuals. For the whole brood—that is, from the time the first larvæ are found on any variety of fruit to the time the last ones are found in the trees—a period of about two months and a half is spent, from the latter part of February to the early part of May.

MOLTS.

After the larvæ have hatched and fed for some seven or eight days they shed their skins, becoming more robust, and ovoid in shape, and in this form they continue until they molt again into the prepupal stage while in the ground. After the larvæ have molted the first time they remain upon the tree from ten days to two weeks before becoming full grown and dropping to the ground. The total time spent upon the tree is from two to three weeks.

LEAVING TREES AND ENTERING GROUND.

On leaving the trees the larvæ do not crawl down but either fall or are knocked off by rains or shaken off by winds. A large number fall with the dropping calyces. Numerous instances were recorded in the year 1910 in which heavy rains knocked off large numbers of larvæ, some of which reached their full growth by feeding upon miner's lettuce, which was at the time the only vegetation growing in this orchard; but many of these immature larvæ were quite small and failed to reach full growth, which is partly responsible for the smaller number of adults in some sections the following year, 1911. The young and only partially grown larvæ that fall off the trees and do not come in contact with any weed or grass in the orchard mostly perish. Only the full-grown larvæ that fall to the ground in cultivated orchards work their way into soil Larvæ that fall off normally do not ascend the trees again, but in some cases in cherry orchards where foliage was near the ground on the trunks of the trees many of the larvæ were noted to crawl back to lower foliage. This would not be likely to occur on pears or prunes, where there is little or no foliage near the ground.

HABITS OF LARVÆ IN THE GROUND.

After the larvæ have pentrated the soil to a sufficient depth they hollow out for themselves a small oblong cell, the inner surface of which is a hard, smooth wall, the cell proper being about one-half inch long. These cells are made for safe places in which the larvæ may pupate or transform to adults. It is here they spend most of the year.

DEPTH TO WHICH LARVÆ GO IN THE GROUND.

The depth that larvæ will penetrate the ground depends largely upon the type of soil. Practically all of the larvæ go below the 3 or 4 inches of a loose topsoil mulch and establish themselves at various depths in the harder soil below. The depths at which larvæ are found in soils vary from 1 to 26 inches. Both of these are extremes and very rarely contain many thrips. In Contra Costa, Solano, and Santa Clara Counties from 50 to 95 per cent of the thrips do not go below 9 to 10 inches, the gravelly soil having the highest percentage of the larvæ nearest the surface. Some of the sedimentary soils along the Sacramento River are very open and porous—a recent alluvial containing a great deal of decaying vegetable matter. The larvæ in such soil may go much deeper, and in many cases they were found in numbers 24 to 26 inches below the surface when none could be found above this depth. In other cases where these light soils have a good heavy sod, thrips have been found in large numbers from 1 to 3 inches below the surface in the cells constructed among the grass roots.

DEPTH TO WHICH LARVÆ GO IN DIFFERENT SOILS.

An absolutely definite statement as to how deep larvæ will go in the various soils, such as gravelly, sandy, sandy loam, sediment loam, and adobe, can not be made, and only comparisons can be given from samples taken from these various soils. On account of the local character of thrips infestation it is important, when one is trying to ascertain the depth of most of the larvæ in an orchard, that several samples be taken, to insure accuracy. The samples should come not only from different parts of the orchard but also from various distances and locations in the vicinity of the same trees. Soil samples for determining the number of thrips per square foot and the depth to which the larvæ go in the soil should be taken at about 2 to 4 feet from the base of the tree.

The samples from which the records given in Table XI were made were taken by sinking galvanized-iron cages into the soil and removing them to the laboratory. The cages had a sliding fourth side which could be be removed so that each layer could be examined by cutting off the desired thickness and sifting the dirt upon a piece of black paper. The

average depth to which larvæ will penetrate in gravelly and sandy loam soils is usually less than in heavy sedimentary loam. In those soils which incline toward the adobe type and in the distinctly adobe soil the larvæ usually go deeper. On account of the cracking of this latter type of soil as it dries out in the spring, and the texture, which is such as to prevent the making of a perfect soil mulch, suitable places for making the cell are not found so near the surface. In soils which can be worked readily except in cases of silt deposits or an abnormal amount of vegetable matter below the surface, very few larvæ, as a rule, penetrate to an unusual depth below the surface; for this reason practically all the soils in the Santa Clara Valley that are badly infested by thrips are such as render possible the obtaining of practicable results from early fall plowing. Table XI shows the comparative depth of larvæ in a number of samples of soil taken from 10 orchards in Santa Clara County. While no sandy soil is present, these samples represent fairly well the different types of soil of the Santa Clara Valley.

TABLE XI.—*Comparative depth of larvæ of the pear thrips in various soil samples, Santa Clara County, Cal.*

Number of layer.	Depth.	Richmond orchard.		Hume orchard.		Landon orchard.		Johnson orchard.		Harkins orchard.		Curry orchard.		Bogen orchard.		Arthur orchard.		Sorosis orchard.		F. Cottle orchard.	
		Heavy clay loam.		Gravelly loam.		Sedimentary loam.		Heavy clay loam near adobe.		Heavy clay loam near adobe.		Heavy sandy loam.		Heavy clay loam.		Heavy clay loam.		Sandy loam.		Sedimentary loam.	
		4 samples.		4 samples.		10 samples.		2 samples.		8 samples.		4 samples.		6 samples.		4 samples.		4 samples.		4 samples.	
		Number of thrips.	Percentage above.	Number of thrips.	Percentage above.	Number of thrips.	Percentage above.	Number of thrips.	Percentage above.	Number of thrips.	Percentage above.	Number of thrips.	Percentage above.	Number of thrips.	Percentage above.	Number of thrips.	Percentage above.	Number of thrips.	Percentage above.	Number of thrips.	Percentage above.
	Inches.																				
4....	3–4	0	0	171	9.92	0	0	1	0.50	6	50.81	0	0	......	......	3	1.02	......	......	17	2.51
5....	4–5	4	3.33	295	27.01	249	8.41	16	8.64	32	5.15	2	1.50	3	0.80	7	3.41	1	0.79	89	15.65
6....	5–6	17	17.50	393	49.21	518	25.92	79	49.45	54	12.47	23	18.79	29	8.62	7	5.80	14	11.90	134	35.34
7....	6–7	39	50.00	240	63.13	829	53.94	81	89.40	136	30.89	7	24.06	39	19.14	34	17.40	55	55.55	148	57.19
8....	7–8	29	74.17	261	78.26	501	70.87	5	91.91	168	53.68	39	54.13	45	31.27	91	48.46	25	75.39	101	72.13
9....	8–9	21	91.66	235	92.46	305	81.18	10	96.96	103	67.62	11	61.66	71	50.40	85	77.47	6	80.16	132	91.72
10....	9–10	7	97.50	58	95.82	168	86.85	3	98.98	74	77.64	48	97.76	58	66.04	42	91.84	8	86.50	45	98.26
11....	10–11	3	100.00	47	98.55	172	92.67	2	99.49	67	86.70	3	100.00	41	77.09	17	97.61	9	93.65	7	99.29
12....	11–12	......	......	17	99.54	87	95.27	0	99.49	40	92.14	......	......	26	84.09	4	98.98	6	98.41	2	99.59
13....	12–13	......	......	8	100.00	21	96.59	0	99.49	30	96.20	......	......	25	90.84	3	100.00	1	99.20	1	99.89
14....	13–14	......	......	......	......	76	98.88	0	99.49	15	98.24	......	......	17	95.40	......	......	0	99.20	1	100.00
15....	14–15	......	......	......	......	33	100.00	1	100.00	13	100.00	......	......	12	98.65	......	......	1	100.00	......	......
16....	15–16	......	......	......	......	......	......	......	......	......	......	......	......	4	100.00	......	......	......	......	......	......
Total number of larvæ....		120	......	1,725	......	2,959	......	198	......	738	......	133	......	370	......	293	......	126	......	677	......
Average number of larvæ per square foot........		120	......	1,725	......	1,183	......	396	......	369	......	133	......	247	......	293	......	126	......	677	......

In Contra Costa County the greater portion of the orchard area is on the distinctively adobe soil. It is a noticeable fact that the larvæ penetrate this soil to a greater depth than they do the hard gravelly soils, probably owing to the greater prevalence of cracks. An examination of Table XII, which is the record of the results of soil examinations from five pear orchards and one prune orchard during the winter of 1908–09, shows that all of the larvæ in the hard gravelly soils were within 8 inches of the surface, while in the adobe soil only 79 per cent were found at this depth, the other 21 per cent being between 8 and 13 inches below the surface.

TABLE XII.—*Comparative depth of larvæ of the pear thrips in various soils near Walnut Creek, Contra Costa County, Cal.*

Pear and prune orchards.					
Anderson, F. A. Bancroft, and Whitman (pear), and Jones (prune) orchards. Heavy loam to adobe.				Wescott and H. H. Bancroft (pear) orchards. Hard, sandy, gravelly soil.	
Number of layer.	Depth.	24 samples.		12 samples.	
		Number of thrips.	Per cent above.	Number of thrips.	Per cent above.
	Inches.				
2	1–2	0	....	3	3.33
3	2–3	0	....	3	6.66
4	3–4	0	....	9	14.44
5	4–5	76	10.33	18	36.66
6	5–6	276	47.83	33	73.33
7	6–7	152	68.70	18	93.33
8	7–8	82	79.98	6	100.00
9	8–9	48	86.23	0	....
10	9–10	32	90.57	0	....
11	10–11	42	96.28	0	....
12	11–12	24	99.55	0	....
13	12–13	4	100.00	0	....
Total number of larvæ		736	....	90	....
Average number of larvæ per square foot		123	....	30	....

AREA AROUND DIFFERENT TREES IN WHICH THRIPS ARE MOST NUMEROUS.

The area around trees in which thrips are most numerous would usually be within a radius of 6 to 8 feet of the base in prune orchards where the trees are from 22 to 24 feet apart. Under prune trees which are from 18 to 20 feet apart, and where the branches overlap, the area infested will be more uniform, and more thrips will be present midway between the rows than nearer the base, as such trees, growing close together, usually do not have so many smaller limbs in the center of the tree as nearer the end of the branches. Pear trees are more upright and compact in growth; hence the greater percentage of the larvæ are near the trunk of the tree, and in the

average Bartlett pear orchard most of the larvæ in the ground are within a radius of 2 to 3 feet of the base of the tree.

TIME SPENT AS LARVÆ IN GROUND.

The time spent by larvæ in the ground before pupating varies. The minimum time is about 2 months, with a maximum of about 8 months, while most of the larvæ will spend about 5 to 6 months within the soil before pupating. Of many examinations of soil samples in Contra Costa and Solano Counties no larvæ were found after November 29; all had pupated prior to this time.

PUPÆ.

STAGES.

As soon as the white larva gets ready for transformation it sheds its skin and develops into what is called the prepupa, which is also white and resembles somewhat the full-grown larva, although also having some features of the adult. In this stage the legs resemble slightly the legs of the adult and the short wing pads extend to about the end of the third or fourth abdominal segment. The antennæ in this stage do not project over the back, as in the case of the pupa or second stage, but project latero-caudad. The exact length of time spent in this prepupal stage has not been ascertained, but from observations made upon other Thysanoptera by the writers this stage is usually very short and in the pear thrips probably does not last more than a week or 10 days before the prepupal skin is shed and the insect passes into the second pupal stage or real pupa.

TIME OF FIRST, MAXIMUM, AND LAST PUPATION.

The earliest pupæ are found during the month of May, and these are very rare. It is possible that these will form late-emerging adults, but more than likely they are premature larvæ that are sickly or infected with some fungous organism which causes them to develop prematurely. All of these early pupæ probably die and fail to reach the adult form. A few pupæ can be found the latter part of July, and there is a gradual increase in numbers through August and September. During the month of October, however, pupation reaches its maximum and may continue through November and into December, by which time it has practically ceased.

Samples taken from orchards in July and August show some pupæ, while sometimes large numbers of samples taken from the same orchards in September fail to show the presence of any. Table XIII shows the relative number of early pupæ and of larvæ found in the Santa Clara Valley during the summer of 1909. Two samples of soil were taken from each orchard for each examination.

TABLE XIII.—*Comparative number of pupæ and larvæ of the pear thrips found in the soil during July and August, 1909, San Jose, Cal.*

Landon and Cottle prune orchards.					
Sample Nos.	Date examined.	Larvæ.		Pupæ.	
		Number.	Per cent.	Number.	Per cent.
	1909.				
30–33	July 15	556	99	66	1
34–37	20	127	100		
38–41	28	67	86	11	14
42–45	Aug. 3	44	94	4	6
46–49	17	22	100		
50–53	17	165	87	22	13
54–57	23	65	80	13	20
58–61	23	93	82	18	19

The time of pupation varies considerably with different orchards; for instance, in orchards where irrigation is practiced in the early fall, pupation probably starts at an earlier date than in orchards where this custom is not followed. Furthermore, from a number of examinations made the past two years it seems evident that pupation begins earlier in those orchards having a heavy sedimentary soil than in orchards which have a light, gravelly soil. Fall plowing would necessarily be more effective upon orchards which have a gravelly soil on account of this habit of late pupation, which would enable the owners to wait until the fall rains have started before plowing, and also because a larger number of thrips are near the surface.

EFFECT OF WEATHER CONDITIONS UPON PUPATION.

It is hardly probable that temperature conditions affect the length of the pupal stage of the pear thrips very greatly, since the ground does not freeze in the winter, except in the Eastern States, and the mean temperature at 6 to 9 inches below the surface for the year around is probably more even than it is above the ground. An early, wet fall would probably cause the thrips to pupate earlier than would be the case in a dry season.

The time spent in the pupal stage varies from one to four months, while the normal time for most of the pupæ is about two months.

ADULTS IN WINTER.

The first adults appear in the ground in late October, the number increasing gradually until December to early January, by which time practically all pupæ have transformed to adults. The time spent in the ground as adults before emerging and appearing on the trees varies from a minimum of one month to a possible maximum of five months, averaging, however, about three months.

SEASONAL HISTORY.

Adult thrips first appear in early February upon the fruit buds and continue to emerge until in the early part of April, appearing in maximum numbers from February 22 to March 10, thus covering the entire period of swelling of buds and blossoming of trees. By the time the fruit buds have swollen sufficiently to separate slightly the bud scales at the tip the adults force their way within, feeding upon the tenderest parts of the buds. Egg laying usually begins when the first leaf surface or fruit stems are exposed, depending somewhat upon the variety of fruit attacked. First oviposition usually occurs the latter part of February and the last toward the middle of April, while maximum oviposition occurs from about March 10 to April 1. The majority of eggs are deposited in the fruit stems, young fruit, and leaf stems, and require from 4 to 16 days to hatch, averaging about 8 days.

By the time Bartlett pear and French prune trees are breaking into full bloom the adult thrips have done practically all of the injury they are able to accomplish. Injury by adult thrips is distinctly associated with the fruit buds before blossoming.

Larvæ first appear in numbers toward the latter part of March and can be found upon the trees up to the middle of May. They appear in maximum numbers from April 1 to April 15.

The larvæ feed upon the foliage and young fruit, causing on the latter the well-known thrips scab, and individuals remain on the trees for two to three weeks in attaining their growth, the entire brood of larvæ requiring 8 to 10 weeks from the first-appearing to the last-disappearing individuals.

All of the larvæ have dropped from the trees by the middle of May and penetrated the soil to a depth of from 1 to 26 inches, depending upon the type and condition of same, in most cases the majority being within 8 to 9 inches of the surface.

Sometimes in July a few larvæ transform into the tender pupæ, and by October the pupæ are in maximum numbers, the last larvæ pupating in November. The pupal stage lasts from one to four months, the usual time being about two months.

Early in February adults, which, in some instances, have remained as such for several months in the ground, appear upon the trees and wait for the first opening of buds, when they begin the work of destruction.

NATURAL ENEMIES.

Probably no single order of insects of such great economic importance has so few effective natural enemies as the Thysanoptera. This is partly due to the small size of the insects belonging to this order, their manner of working, their great activity, their unique life history, and the fact that not more than six or seven species in the order have ever accomplished any great economic damage. Practi-

cally all the attempts to control the thrips by artificial means have been within the United States. Of the few natural enemies of Thysanoptera that do exist, the most important seems to be *Triphleps insidiosus* Say, which feeds upon thrips by impaling them upon its beak and sucking out the juices. *Megilla maculata* De G., chrysopid larvæ, and syrphid larvæ have also been found feeding upon thrips. Uzel[1] has found *Triphleps minutus* L. preying on thrips and credits Heeger with the finding of *Scymnus ater* Kug., *Gyrophaena manca* Er., and some fly larvæ feeding in the same manner. Hinds[2] mentions having found some small scarlet acarid attached to the membranous area of the body of *Anaphothrips striatus* Osborn. Uzel [1] and Quaintance [3] have both found eggs of nematode worms within the bodies of adult thrips. J. C. Crawford[4] in December, 1911, gives a short account of *Thripoctenus russelli* Crawford, a new internal parasite of Thysanoptera and later Russell[5] publishes a more complete account of the life history and habits of this parasite. The first recorded host of *T. russelli* was *Heliothrips fasciatus* Pergande, but it has been reared from *Thrips tabaci* Lind. and *Frankliniella tritici* Fitch. Its oviposition has been observed in *Heliothrips femoralis* Reuter and *H. haemorrhoidalis* Bouché. Great hopes were entertained by Mr. Russell for its colonization among related injurious Thysanoptera.

Of plant parasites, Thaxter [6] has taken an Empusa fungus destroying a species of thrips in the larval, adult, and pupal stages, and Petit [7] and Hinds [8] have found a fungus which they thought was causing some of the species of thrips to die.

No effective natural enemy has been found preying upon the pear thrips. Moulton [9] mentions some raphidians feeding upon the younger forms of this species and has also found a species of ant killing individuals. He mentions [10] a fungus which he regarded as parasitic during the season of 1905 and 1906, but the last three or four years have failed to show that any appreciable amount of benefit has been derived from it. Very little of the fungus has been observed during the years 1908, 1909, and 1910.

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[1] Uzel, Heinrich. Monographie der Ordnung Thysanoptera. Königgrätz, 1895, 472 p. 10 pl. See p. 362.

[2] Hinds, W. E. Contribution to a Monograph of the Insects of the Order Thysanoptera Inhabiting North America. *In* Proc. U. S. N. Mus., vol. 26, p. 119, 1902.

[3] Quaintance, A. L. The Strawberry Thrips and the Onion Thrips. Fla. Agr. Exp. Sta., Bul. 46, p. 79–114, 12 figs. July, 1898.

[4] Crawford, J. C. Two new Hymenoptera. *In* Proc. Ent. Soc. Wash., v. 13, no. 4, p. 233–234, 1911.

[5] Russell, H. M. An Internal Parasite of Thysanoptera [*Thripoctenus russelli*]. U. S. Dept. Agr., Bur. Ent., Tech. Ser. no. 23, pt. 2, p. 25–52, figs. 11, Apr. 27, 1912.

[6] Thaxter, Roland. The Entomophthoreae of the United States. *In* Mem. Boston Soc. Nat. Hist., v. 4, no. 6, p. 134–201, pls. 14–21, Apr., 1888. See p. 151, 172, 174, pl. xvii, figs. 200–219.

[7] Pettit, Rufus H. Some Insects of the Year 1898. Mich. State Agr. Coll. Exp. Sta., Bul. 175, p. 341–373, 20 figs, July, 1899. See p. 343–345, figs. 1, 2.

[8] Loc. cit.

[9] Moulton, Dudley. The Pear Thrips (*Euthrips pyri* Daniel). U. S. Dept. Agr., Bur. Ent., Bul. 68, pt. 1, rev., p. 14, Sept. 20, 1909.

[10] Op. cit., p. 15.

UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 174

Contribution from the Bureau of Plant Industry
WM. A. TAYLOR, Chief

Washington, D. C. ▼ April 15, 1915

FARM EXPERIENCE WITH THE TRACTOR

By

ARNOLD P. YERKES, Scientific Assistant,
and H. H. MOWRY, Assistant Agriculturist, Office of Farm Management

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BULLETIN OF THE
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FARM EXPERIENCE WITH THE TRACTOR.

By Arnold P. Yerkes, *Scientific Assistant*, and H. H. Mowry, *Assistant Agriculturist, Office of Farm Management.*

CONTENTS.

INTRODUCTION.

Modern agriculture requires an enormous amount of power to perform the annual farm operations, and there is a continuous, potential demand for any device that will afford cheaper and more convenient power on the farm. This situation has stimulated the production of many types of mechanical substitutes for the farm horse.

Although mechanical power outfits for farm operations have been used in large and increasing numbers for several years, there have been very few reliable data available to the public on the performance of these outfits under ordinary service conditions. Much of the information which has been offered has originated from sources which would indicate that the presentation of the subject would be a biased one or has been furnished by men who were obtaining good, perhaps

Note.—This bulletin is intended to make available to farmers who contemplate buying a tractor the experience of many other farmers who have already used one; it is suitable for distribution west of the Mississippi River.

exceptional, results from their outfits. At the same time, men who have not succeeded are not usually inclined or afforded an opportunity to make their experiences generally known. It is necessary to consider carefully the results obtained by all users, whether they have succeeded or failed, in order to obtain correct information as to the present status of the farm tractor. The data in this bulletin are based upon the experience of a large number of users in both classes. It is important for everyone interested that a reliable and impartial survey be made available. The relative efficiency of various makes of tractors is not considered in this bulletin. It is obvious, however, that this factor of the efficiency of some particular machine may be a most important one to the individual farmer.

DESIGNATION OF TRACTORS.

Owing to the numerous terms used to designate tractors in various sections, it may be well to state that in this bulletin the term "gas tractor" is used to designate those machines which derive their power from an internal-combustion engine burning a vaporized fuel (regardless of the kind of oil burned), which are designed for pulling implements and for doing stationary work. When the term "gasoline tractor" occurs it denotes an outfit of the kind just mentioned in which gasoline is regularly used for fuel. Similarly, the term "kerosene tractor" is used to denote a "gas tractor" in which kerosene is the ordinary fuel. By a "steam tractor" is meant an outfit deriving its power from steam generated in a boiler, heated by means of a fire of coal, wood, straw, or similar fuel.

The smaller machines, designed especially for cultivation, plowing, etc., commonly known as "autoplows" and "autocultivators," in which the tillage implement and power plant are combined in one unit, have not been considered in this bulletin, as these do not properly come under the title of tractors. While there are numerous types of these small self-propelled plows and cultivators intended particularly for use on small farms, few of them have been in actual service long enough and in sufficient numbers to demonstrate their ability to perform the work for which they are intended.

Nor should the data or remarks contained herein be considered as applying to the various types of small tractors designed to pull two or three plow bottoms and selling at a comparatively low figure, large numbers of which have been placed on the market during the past few months. These small, low-priced outfits represent the latest phase of the development of the farm tractor and may fairly be considered as belonging to a different class than those under discussion in this bulletin. While they give promise of proving an economical source of power for a great deal of the field and stationary work on

the average farm, they have not been in actual use under service conditions for a sufficient length of time to demonstrate their utility conclusively.

STEAM AND GAS TRACTORS.

The self-propelled steam thrashing engine was the prototype of the modern steam tractor, the latter differing from the former mainly in the size of the drivewheels and transmission gears. In other words, the steam tractor, generally speaking, was an outfit designed primarily for stationary use, but it was gradually adapted to the heavier work of hauling implements and to other work requiring power. A number of years were required for its development, but it finally proved its value on the large areas of prairie opened up for settlement in the West.

At its best, however, it had several serious disadvantages. It burned bulky fuels, of which it could carry only a limited supply and which required considerable time and labor in conveyance. It consumed a large amount of water, which in a dry country was frequently a serious handicap. It was heavy and cumbersome and required a man of considerable ability to operate it properly. It ordinarily employed a crew of three to five men and of two to four horses. A delay of half an hour or more was often experienced in getting up steam pressure sufficient to commence work, and considerable fuel was consumed in keeping up steam during stops. In many cases the fire would be maintained all night in order to have the engine ready for work the next morning.

These objectionable features were practically overcome by the gas tractor. It burned a fuel of less bulk and attained a higher thermal efficiency, so that it could easily carry sufficient fuel for a half day's run, and in many cases for much longer. One 2-horse load of fuel would keep the engine in operation for several days. It used comparatively little water, and, if desired, a low-priced oil could be substituted for water in the cooling system. It weighed less per unit of power than the steam tractor, was shorter, and could therefore turn in less space. While it demanded a thoroughly competent operator in order to secure the best results, he could easily attend to the entire operation of the engine and would frequently find time to operate the plows as well, although the crew usually consisted of two men and occasionally of three men and two horses. The motor could be started in a moment's time, and no fuel need be consumed when the outfit was idle.

After the steam tractor had been used for plowing for several years, an insistent demand developed for a plowing outfit without the disadvantages of the steam tractor. The early gas tractors were built largely to meet this demand. The gas tractor has therefore

been developed primarily as a plowing engine, with belt work a secondary consideration. Although it was actually superior to the steam tractor in the ways mentioned, it was nearly a decade before it developed sufficiently to prove this superiority and became a real competitor with the steam tractor. Most of its growth has occurred during the past 11 years, and in considering the rapidity with which it has been made it might at first appear that it must have been due to its superiority over both the horse and steam tractor as prime movers for the farm. As to its superiority over the steam tractor there is no doubt. The sales of steam tractors for farm work other than thrashing fell off as those of the gas tractor increased, and the steam tractor is seldom found to-day except in sections where suitable fuel is cheap and convenient, thus giving it an advantage over the gas tractor. The decline in the number of steam tractors used for farm work is shown by the age distribution of those reported:

One year old, 37; 2 years old, 65; 3 years old, 65; 4 years old, 88; 5 years old, 76; 6 years old, 33; 7 years old, 25; 8 years old, 24.

THE GAS TRACTOR AND THE HORSE.

While the gas tractor has almost completely replaced the steam tractor, as has been stated, neither the steam nor gas tractor has affected the sale or use of farm horses to any great extent. (See Tables XXII and XXIII.)

A careful study of the subject shows clearly that the rapid growth of the gas tractor was not due to its superiority over the horse, but to the fact that large tracts of unbroken prairie land were being opened up in the West and that sufficient horses were not available to break the ground and bring it under cultivation. Gas tractors could be, and were, manufactured in a much shorter time than it would have taken to raise the necessary horses for this work. But as this new country developed, horses were rapidly imported, colts were raised, and more and more of the farm work was performed with horses. Quite frequently the tractor which had broken the prairie and brought it under cultivation was entirely replaced by them.

A similar condition existed recently in Kansas. An epidemic diminished the number of farm horses in that State by thousands, and the number remaining was insufficient to perform the field work. Immediately hundreds of traction engines were shipped into the State to meet the power requirements. Whether these machines will retain the ground thus opened to them remains to be seen. Under similar conditions in other States they have not done so, indicating that they are either not as satisfactory as horses for farm work or are more expensive.

The failure of the gas tractor to maintain its position as the principal prime mover in those sections where it was first introduced was

apparently not anticipated by those interested in its production. On account of its failure to maintain this position the heavy demand for gas tractors in those sections was only temporary, and an oversupply of tractors was placed upon the market, resulting in depression in the industry. Similar overproduction due to lack of foresight has occurred in other lines of farm equipment, one of the best examples being the oversupply of grain harvesters during the period of rapid multiplication of the improved models.

Generally speaking, the farm tractor has thus far merely supplemented the work of the farm horse and relieved him of the heavier work; it has not actually replaced horses to any considerable extent.

TRACTOR RATINGS.

When internal-combustion tractors were first introduced, there was considerable confusion among engine users as to their ratings, owing to the fact that several methods were used in computing and designating their horsepower. There are still several formulas used in computing the power developed by the motor, but the terms by which the power is denoted have become more uniform and more generally understood. The terms "brake" or "belt" horsepower are used to denote the total amount of power which the engine will develop and transmit to a belt for stationary work, such as thrashing. This amount of power may be computed or ascertained by actual measurement with a proper apparatus.

The "drawbar" horsepower is the belt horsepower minus the amount of power required to propel the weight of the tractor. Most tractors require approximately 50 per cent of the total power developed by the engine to move its own weight, leaving the remainder available for pulling other implements. The amount of power which is actually exerted on the drawbar varies, of course, with the weight and construction of the tractor, and may be either computed or measured with a dynamometer. The tractor ratings are ordinarily expressed by writing the brake horsepower after the drawbar horsepower; thus, "30–60" would indicate a tractor having a pull of 30 horsepower on the drawbar and developing 60 for stationary work.

The term "horsepower" denotes an amount of power equivalent to that developed by a 1,500-pound horse moving at the rate of $2\frac{1}{2}$ miles per hour and exerting a pull equal to one-tenth of his own weight, or 150 pounds. This represents a power output capable of raising a weight of 33,000 pounds to a height of one foot in one minute, and these figures are commonly used in computing the power developed by an engine. A pull equal to one-tenth of his weight is considered a normal load for a horse. As most farm horses weigh less than 1,500 pounds, it is apparent that they do not ordinarily furnish a

full horsepower. A 1,200-pound horse moving at the rate of $2\frac{1}{2}$ miles per hour and exerting a pull of 120 pounds (one-tenth of his weight) would develop only four-fifths of a horsepower. Thus, an engine delivering 20 horsepower at the drawbar would be exerting a stronger pull than 20 horses (averaging less than 1,500 pounds in weight) normally do hour after hour. It should be borne in mind, however, that the engine is capable of delivering at the drawbar in an emergency but a fraction in excess of its rating of 20 horsepower, while 20 average horses are able for a short time to pull several times their normal load; that is, the engine might be overloaded to deliver 25 horsepower, while the 20 horses can be so urged as to deliver 30, 40, 60, or more horsepower for very short periods of time.

SOURCE OF DATA.

In obtaining the data on which this bulletin is based, several hundred owners in sections where tractors are most widely used were personally visited, and conditions were observed and interviews had with farmers using tractors as well as with those who did not use them. At the same time the opinions of business men with regard to the use of tractors by farmers in their vicinity were secured and brief histories of the experience of users were recorded.

A letter was addressed to all bankers located in the farming sections of the United States lying west of the Mississippi River, requesting their opinions as to the effect of the tractor on the farming industry in their vicinity, the desirability of the tractor as an investment for a farmer, their practice regarding the loan of money for the purchase of a tractor, and related questions. (See Table II.)

A letter was addressed to more than 13,000 tractor owners, inclosing a list of questions to be answered, the replies to which were tabulated and are shown in the following pages. The distribution of these tractor users by States is shown in Table I. Replies were received from about 40 per cent of the men addressed, but many of the reports were discarded because tractors had not been used for a sufficient length of time to enable their owners to form an opinion as to their merits. However, more than 2,000 men who had operated their outfits for one or more seasons furnished detailed reports.

TABLE I.—*Distribution of tractors in States west of the Mississippi River, showing the approximate number of owners reported by bankers.*

State.	Tractor owners.	State.	Tractor owners.	State.	Tractor owners.
North Dakota	3,200	Texas	650	Arkansas	80
South Dakota	2,100	Missouri	345	Arizona	20
Kansas	1,205	Oklahoma	335	New Mexico	15
Iowa	1,200	Colorado	265	Nevada	5
Minnesota	1,060	Wyoming	130	Utah	5
Montana	950	Oregon	125		
Nebraska	730	Idaho	105	Total	13,327
California	700	Washington	102		

OBSERVATIONS OF BUSINESS MEN.

Most of the inquiries to business men were addressed to bankers. It is believed that bankers have a more intimate knowledge of the financial standing of the farmers of their community than most other classes of business men and are also more likely to furnish an unbiased and unprejudiced opinion, based on their knowledge of the financial success of the men who are farming with horses and those who are using tractors. The prosperity of the bankers of a community depends largely upon the prosperity of their patrons, and they naturally keep well informed on all factors influencing the welfare of the community. It appears from many of the answers that the writers had been carefully observing the effect of farm tractors for several years, and their conclusions were based on actual knowledge of the general prosperity of the men who farmed with horses and those who used tractors.

The replies received from all classes of business men showed that where tractors had been used to any great extent or for a considerable length of time the business interests have become prejudiced against them and believe they have had an injurious effect on the farming community and general prosperity of the country. Hundreds of facts and arguments were furnished in support of these opinions, which were not in a form permitting tabulation. The principal reason advanced seems to be the fact that a great many men who have purchased tractors have failed to make them pay, and a large percentage, having bought expensive outfits on time, lost their entire property through foreclosure proceedings and judgments on notes.

It is unfair, however, to ascribe all of these failures to the inefficiency of the tractor, as faulty operation had its share. A very important contributing cause has been the poor business management and judgment of the farmer in incurring an obligation nearly or quite equal to the entire value of his property with no means of meeting it except the production of a good crop or the possible performance of a large amount of lucrative custom work. While a good crop might save him from bankruptcy, he would be more properly termed "lucky" than a good manager. The failure of a crop the first year after the purchase of the tractor has often been sufficient to ruin the owner, while serious breaks or other accidents have frequently accomplished the same result.

Without referring further to the reasons for their opinions, most of the business men consulted do not consider the tractor a good investment for the average farmer. The opinions of bankers as to the effect the tractors have had on the farming industry and their desirability as an investment for the average farmer are shown in Table II. In this table the States are arranged according to the number of

tractor owners known to the bankers, but this is probably the order in which they would appear if they were arranged according to natural conditions most favorable to the tractors and possibly also as to the length of time during which such machines have been used in these States, respectively.

TABLE II.—*Bankers' opinions regarding the tractor.*

States (arranged according to number of tractor owners known to bankers).	Answers of bankers to questions indicated below.			
	Has traction farming had a favorable or unfavorable effect upon the farming industry in your vicinity?		Do you consider a traction engine a good investment for the average farmer in your neighborhood?	
	Unfavorable.	Favorable.	No.	Yes.
North Dakota	343	57	422	20
South Dakota	124	58	225	48
Kansas	83	87	172	26
Iowa	17	59	65	17
Minnesota	57	53	144	11
Montana	87	26	116	8
Nebraska	22	35	61	10
California	4	90	43	34
Texas	23	51	61	23
Missouri	18	16	28	3
Oklahoma	18	23	49	5
Colorado	16	17	33	3
Wyoming	6	12	17	4
Oregon	5	11	12	2
Idaho	5	5	11	4
Washington	7	4	11	2
Arkansas	2	5	5	4
Utah	5	4	11	1
Total	842	613	1,486	225

Each of the bankers whose answers are included in this tabulation knew at least three users of tractors, while most of them knew a much greater number, the average being about 10. It will be observed from this table that while 842 bankers believe the tractor has had an unfavorable effect on the farming industry and 613 state the effect to be favorable, the number of bankers who are of the opinion that the tractor is a good investment for a farmer is only 225, while 1,486 think that it is not. Bankers realize that the tractor has been a benefit to the community in helping to break and open up to cultivation large tracts of virgin land, but they also realize that the risk of this enterprise, as well as much of the expense, has been borne by the individual farmer. Nearly 87 per cent of business men who have had an opportunity to observe the results of tractor farming consider that a tractor is a poor investment for a farmer.

OPINIONS OF TRACTOR OWNERS.

The opinions of the men who have used tractors corroborate the views of the bankers. In reply to the question, "Do you consider a traction engine a good investment financially for a farmer in your

vicinity?" there were 876 who answered "no" and 891 who answered "yes." Of those answering this question, 748 had used their tractor for only one season. The answers of the men who had used the tractor through two or more seasons show 592 negative and 427 affirmative replies. Practically all of the men from whom replies were received were using tractors at the end of 1913, and those who had previously tried them but had discontinued their use are not, therefore, included. It may safely be assumed that nearly all of the latter class would answer the above question in the negative, which would more than double the number of men answering "no," as there are hundreds of men who have discontinued the use of the tractor after a trial. Accurate figures on this point are difficult to secure, owing to duplication among the past users of tractors reported, but a conservative estimate obtained by using the number reported by bankers located in widely separated sections of Montana indicates that more than 400 men have discontinued the use of the tractor for farm work in that State. The answers of present owners of tractors to the above questions are shown in Table III.

TABLE III.—*Answers of tractor owners to the question, "Do you consider the traction engine a good investment financially for a farmer in your vicinity?"*

State.	First season.		Second season.		Third season.		Fourth season.	
	Yes.	No.	Yes.	No.	Yes.	No.	Yes.	No.
North Dakota	108	106	73	154	25	86	15	32
South Dakota	39	28	28	22	16	19	15	14
Kansas	56	22	26	22	9	9	5	5
Minnesota	24	27	37	35	13	12	3	7
Montana	26	26	23	38	7	12	2	12
Iowa	52	17	14	13	9	6	3	3
Colorado	42	4	15	9	11	2	2	....
Nebraska	22	13	11	14	4	1	....	3
Texas	25	13	4	8	1	3	....	....
Missouri	15	5	3	3	1	1	2	....
Other States	55	23	16	19	9	4	3	4
Total	464	284	250	337	105	155	50	80
Per cent	62.0	38.0	42.6	57.4	40.4	59.6	38.5	61.5

Table III shows that the percentage of men who believe that the tractor is a poor investment increases with each season's use, until, after four years, 61.5 per cent of the owners are of this opinion. If the opinions of those who have discontinued the use of the tractor could have been included, this percentage would doubtless be increased to 85, thus approximating the judgment of the bankers. For example, 65 per cent of all present tractor owners in Montana have had more than one season's experience, and 65 per cent of these answer the inquiry in the negative. If 65 per cent of the 950 users reported for Montana in Table I, or 617, be taken as the number in that State having more than one year's experience, then 65 per cent of the

latter number, or 400, represents the number of present users who report unfavorably after one season of experience. If to this be added the 400 who have discontinued the use of the tractor in Montana, there appear to be 800 out of 1,017 who hold unfavorable opinions, or about 80 per cent.

In analyzing the reports of users it early became apparent that opinions and estimates furnished by men who had used a tractor for only one season could not be accepted as representing average results, as their answers invariably gave more favorable averages than did those from men who had had experiences of two or more seasons. This is partly due in all probability to the fact that their machines were of better quality than those of previous years, but the differences between the averages are far greater than those existing between the tractors sold early in 1913 and those sold one year previous. The principal reason for these favorable answers is doubtless a natural enthusiasm resulting from the acquisition of new and interesting machines, of which great achievements are expected, but which have not been used for a sufficient time to demonstrate their actual value. The experience gained by the end of the second season, with the novelty gone, the outfit showing the effect of wear and not running so satisfactorily as when new, and the probability of more or less repairing having been necessary, makes the owner better qualified to express an opinion as to the tractor's actual value.

The tractor's efficiency decreases with use, on account of wear. The reports show, however, that it is during the first year of its use, when it should be rendering its maximum amount of service and giving a minimum amount of trouble, that the largest percentage of men change their opinions of the tractor from favorable to unfavorable. It is a reasonable supposition that every purchaser of a tractor believes he is making a good investment at the time of purchase. The data show that after one season's use only 62 per cent retain this opinion, so that it would seem that the results were such as to cause 38 per cent to change their opinion on this point after one year. After two seasons' use more than 57 per cent of present tractor users believe the tractor is a poor investment, and with longer experience this percentage increases.

REPORTS OF SATISFIED AND DISSATISFIED OWNERS.

In order to ascertain whether the owners who expresssed favorable opinions regarding the tractor were actually obtaining better results than those holding opposite views, tabulations were made of the data furnished by these two classes of men, and the averages obtained are shown in Tables IV to VIII, inclusive.

The data compiled from reports of tractor owners shown in Tables IV to VIII are separately given for North Dakota and for all other

States west of the Mississippi River.[1] This separation was made for the following reasons: Sufficient replies were received from owners in North Dakota to give reliable averages. The conditions under which tractors are used in North Dakota are very similar throughout the State, being generally favorable to the tractor on account of the large, level farms, where the types of farming followed are well adapted to the use of mechanical power. Gas tractors have been used in considerable numbers in North Dakota for a greater length of time than in the other States.

SERVICE RENDERED BY TRACTOR.

Table IV shows the average amount of service rendered annually per tractor, together with estimates as to the average life of farm tractors. The figures showing days used per year include custom work of all kinds, as well as stationary work on the home farm. It will be noticed that the number of days the tractor is used per year grows slightly less, as a rule, from year to year, and at the same time the hours lost per day increase.

In connection with the estimated life of the tractor it may be noted that for the group of States the averages are higher for the men who have used the tractor but one season, while in North Dakota they are slightly lower. This is probably partly due to the fact that in making the estimate the men were asked to judge by "observations and experience." In North Dakota many men who had used a tractor for only one year could make a fair estimate of the average life of a tractor from observations of outfits which had been used in their neighborhood, while in other States they have not been so widely used and the estimates are made to a greater extent from personal experience only. There are also other reasons, which will appear in connection with subsequent tables.

Only 24 reports from North Dakota were received from men who had used their tractors more than four years, and about the same number came from the other territory. The age distribution of the tractors reported from North Dakota was as follows:

One year old, 278; 2 years old, 283; 3 years old, 131; 4 years old, 55; 5 years old, 15; 6 years old, 5; 7 years old, 2; 8 years old, 2.

It is known that the number of 4-year-old tractors reported is a very small percentage of the number of tractors actually sold four years ago, much smaller than the percentage reported for the 1 and 2 year old tractors. This would apparently indicate that many of the tractors sold four years ago are no longer in use, and, together with the decrease in the number reported for the third year, might be

[1] The data in the upper half of Tables IV, V, VI, VII, and VIII are all based on the same group of farms, and by combining these parts of tables the complete tabulation for the group may easily be obtained. The same is true of the lower half of these tables.

considered as evidence that the estimated life of the tractor, as furnished by the tractor owners reporting, is too high.

TABLE IV.—*Service rendered annually by tractors on farms in North Dakota and other States west of the Mississippi River, showing the length of life as estimated by the owners.*

[Arranged according to the opinions of owners as to the tractor's desirability as an investment.]

IN THE STATE OF NORTH DAKOTA.

Result of investment as reported by owners.	Average annual use.	Hours in field per day.		Estimated average life of tractor.	Number averaged.	Farms where night work was reported.	
		Spent.	Lost.			Percentage of all tractors.	Average number of nights operated per year.
Men having one season's experience:	*Days.*			*Years.*			
Profitable	87.1	12.5	1.2	8.5	108	14.6	31.8
Unprofitable	69.2	12.4	2.1	5.0	106	13.7	12.9
Men having two seasons' experience:							
Profitable	97.3	13.1	1.4	8.8	73	23.1	26.9
Unprofitable	76.6	12.9	2.7	4.9	154	10.7	16.0
Men having three seasons' experience:							
Profitable	85.2	12.8	1.5	8.8	25	30.0	17.3
Unprofitable	75.6	12.8	2.7	5.4	86	12.9	11.7
Men having four seasons' experience:							
Profitable	92.5	12.6	1.6	8.7	15	10.0	60.0
Unprofitable	73.4	12.0	2.8	5.9	32	8.0	22.5

IN ALL STATES WEST OF THE MISSISSIPPI RIVER EXCEPT NORTH DAKOTA.

Result of investment as reported by owners.	Average annual use.	Hours in field per day: Spent.	Hours in field per day: Lost.	Estimated average life of tractor.	Number averaged.	Percentage of all tractors.	Average number of nights operated per year.
Men having one season's experience:							
Profitable	105.8	11.4	1.3	10.2	356	21.3	26.5
Unprofitable	77.9	11.5	2.2	6.4	178	16.5	13.7
Men having two seasons' experience:							
Profitable	102.1	11.7	1.4	9.7	177	28.6	34.7
Unprofitable	73.9	11.8	2.2	5.0	183	16.0	22.2
Men having three seasons' experience:							
Profitable	98.9	11.6	1.4	9.9	80	16.9	38.9
Unprofitable	73.0	11.6	2.5	5.7	69	5.2	18.3
Men having four seasons' experience:							
Profitable	93.5	11.6	1.6	9.3	35	10.7	22.0
Unprofitable	65.2	11.4	2.6	5.9	48	7.1	38.3

To judge by the estimates, the average life of a tractor in North Dakota is approximately only 6 years, while the average estimated life in other States is about 8 years. It is believed, however, that in the case of estimates on the life of tractors for States other than North Dakota, some allowance must be made for the fact, already mentioned, that most of these estimates are based entirely on the owner's personal experience, which the figures show has been a short one for 80 per cent of the men reporting, whereas for North Dakota the figures are to a great extent based on observation of neighboring tractors as well.

However, the life of a tractor can not be properly expressed in years alone. The tractor is a machine; and, like all machines, its life depends on the amount of work it does and on the care taken of it. This life can be shortened by lack of proper care and by abuse in operation. The number of years a tractor will be available for work on a farm, therefore, depends only partly on the hours it will be required to work each year. But if the machine is given proper care, both when idle and when in use, the amount of work done per year will be the principal factor in determining its length of useful life. Table IV shows that during the working life of a tractor in ordinary farm service the amount of service obtained covers from 3,600 to 11,000 working hours, including both traction and stationary work. From these figures it is apparent that a tractor might be worn out in less than two years if operated day and night continuously, while, on the other hand, if used only intermittently its life may be extended over a number of years, with proper protection from deteriorating influences when not in use. It might seem at first thought that a tractor could be made to last indefinitely by replacing worn-out parts with new ones, but there comes a time when the cost of such replacements becomes prohibitive and it is more economical to discard the old tractor and purchase a new one. The tractor's life is, then, the length of time it can be used before the repairs become so expensive as to make its further use uneconomical.

While Table III showed the number of owners who believe the tractor to be a profitable investment, there were two related questions submitted to the owners which are not shown in the tabulations. These were "All things considered, is the tractor more satisfactory than horses?" and "Is it cheaper?" The answers received to these questions agree in many cases with those shown in Table III, but it is interesting to note that among the men who believed the tractor to be a good investment the number reporting the tractor to be cheaper than horses is greater than the number stating that it is more satisfactory than horses. On the other hand, among the men believing that the tractor is an unprofitable investment, the number stating that it is not cheaper than horses is less than the number stating that it is not as satisfactory.

This would seem to indicate that among the successful owners the tractor's economy has been a greater factor than its general utility, while among the unsuccessful owners the expense has been a more important consideration than its unsatisfactory operation.

FUELS USED.

Table V shows the number of engines in each group which burn gasoline, kerosene, and motor spirits, respectively. From this table it will be seen that the percentage of kerosene tractors is slightly

greater in each group where the owners believe the tractor is profitable than in the groups where the owners state that the tractor is unprofitable. While this difference is in no case greater than 13 per cent, it is invariably present, which indicates that it has probably had some influence on the opinions of the owners. A further comparison of gasoline and kerosene tractors will be found in Table IX.

TABLE V.—*Tractors using different fuels on farms in North Dakota and other States west of the Mississippi River.*

[Arranged according to the opinions of owners as to the tractor's desirability as an investment.]

IN THE STATE OF NORTH DAKOTA.

Result of investment as reported by owners.	Gasoline.		Kerosene.		Motor spirits.		Fuel not reported.
	Number using.	Percentage of number reported.	Number using.	Percentage of number reported.	Number using.	Percentage of number reported.	
First season:							
Profitable	37	48.7	33	43.4	6	7.9	32
Unprofitable	50	63.3	27	34.2	2	2.5	27
Second season:							
Profitable	30	49.2	29	47.5	2	3.3	12
Unprofitable	77	62.6	45	36.6	1	.8	31
Third season:							
Profitable	14	60.9	8	34.8	1	4.3	2
Unprofitable	41	64.1	21	32.8	2	3.1	22
Fourth season:							
Profitable	6	46.2	7	53.8	0	....	2
Unprofitable	16	59.3	11	40.7	0	....	5

IN ALL STATES WEST OF THE MISSISSIPPI RIVER EXCEPT NORTH DAKOTA.

Result of investment as reported by owners.	Gasoline. Number using.	Gasoline. Percentage of number reported.	Kerosene. Number using.	Kerosene. Percentage of number reported.	Motor spirits. Number using.	Motor spirits. Percentage of number reported.	Fuel not reported.
First season:							
Profitable	117	46.2	133	52.6	3	1.2	49
Unprofitable	78	53.4	65	44.5	3	2.1	25
Second season:							
Profitable	70	52.2	60	44.8	4	3.0	26
Unprofitable	86	59.3	59	40.7	0	....	29
Third season:							
Profitable	34	60.7	20	35.7	2	3.6	12
Unprofitable	39	72.2	15	27.8	0	....	13
Fourth season:							
Profitable	14	51.9	13	48.1	0	....	5
Unprofitable	19	52.8	17	47.2	0	....	12

AMOUNT OF MOTIVE POWER PER FARM.

In Table VI are comparisons of the amount and value of motive power maintained by the two classes of tractor users which are being considered, together with the value of special equipment purchased for use with the tractor and the average size of farms for each group.

Little difference is shown in the average sizes of tractors, in their cost, or in the value of special equipment for the tractor. But the men who find the tractor profitable, although they show a greater average acreage, do not keep so many horses as those who reported unfavorably. A comparison of results obtained on different sizes of farms is shown in Table XIX.

TABLE VI.—*Comparison of the average amount and value of motive power maintained by tractor users on farms in North Dakota and other States west of the Mississippi River.*

[Arranged according to the opinions of owners as to the tractor's desirability as an investment.]

IN THE STATE OF NORTH DAKOTA.

Result of investment as reported by owners.	Drawbar horse-power of tractors.	Cost of tractors.	Value of special equip-ment for tractors.	Horses kept.		Size of farms (acres).
				Present number.	Value.	
First season:						
Profitable	22.9	$2,474	$617	8.9	$1,526	785
Unprofitable	23.2	2,467	650	11.1	1,849	763
Second season:						
Profitable	24.7	2,621	753	10.4	1,831	924
Unprofitable	24.3	2,548	720	13.8	2,241	870
Third season:						
Profitable	23.0	2,572	670	10.3	1,724	783
Unprofitable	24.6	2,604	725	10.4	1,689	719
Fourth season:						
Profitable	23.2	2,247	706	11.6	1,896	896
Unprofitable	21.4	2,430	725	13.7	2,203	846
IN ALL STATES WEST OF THE MISSISSIPPI RIVER EXCEPT NORTH DAKOTA.						
First season:						
Profitable	21.9	$2,348	$496	8.8	$1,405	666
Unprofitable	23.7	2,330	528	10.1	1,565	548
Second season:						
Profitable	22.9	2,426	574	8.7	1,398	682
Unprofitable	22.8	2,454	613	10.1	1,595	664
Third season:						
Profitable	22.8	2,549	601	13.8	2,010	847
Unprofitable	21.8	2,478	620	10.5	1,607	759
Fourth season:						
Profitable	19.3	2,252	529	11.5	1,794	714
Unprofitable	22.1	2,322	688	10.8	1,671	614

CUSTOM WORK.

Table VII shows the number of owners in each of the two classes that are being compared who use their tractors for custom work. From these it will be seen that the percentage of men who do custom work, as well as the percentage of men who state that custom work is profitable, is larger among the owners who find the tractor profitable than among the second class of owners. The difference in the prices received is not very marked nor very regular and apparently bears little relation to the percentage of men reporting custom work unprofitable. For a comparison of averages from men who state that custom work is profitable and from those who find it unprofitable, see Table XX.

TABLE VII.—*Custom work done by tractor owners on farms in North Dakota and other States west of the Mississippi River.*

[Arranged according to the opinions of owners as to the tractor's desirability as an investment.]

IN THE STATE OF NORTH DAKOTA.

Result of investment as reported by owners.	Number reporting.	Doing custom work.		Finding custom work profitable.	
		Number.	Per cent.	Number.	Per cent.
Men having one season's experience:					
Profitable	104	76	73.1	64	87.7
Unprofitable	103	56	54.4	21	43.7
Men having two seasons' experience:					
Profitable	72	59	81.9	48	87.3
Unprofitable	149	95	63.8	22	27.8
Men having three seasons' experience:					
Profitable	25	21	84.0	19	95.0
Unprofitable	85	52	61.2	13	27.7
Men having four seasons' experience:					
Profitable	15	10	66.7	8	88.9
Unprofitable	32	25	78.1	9	39.1

IN ALL STATES WEST OF THE MISSISSIPPI RIVER EXCEPT NORTH DAKOTA.

Result of investment as reported by owners.	Number reporting.	Doing custom work: Number.	Doing custom work: Per cent.	Finding custom work profitable: Number.	Finding custom work profitable: Per cent.
Men having one season's experience:					
Profitable	341	237	69.5	199	88.8
Unprofitable	172	120	69.8	60	54.5
Men having two seasons' experience:					
Profitable	170	130	76.5	102	87.9
Unprofitable	177	115	65.0	43	41.0
Men having three seasons' experience:					
Profitable	78	59	75.6	50	89.3
Unprofitable	67	46	68.7	14	34.1
Men having four seasons' experience:					
Profitable	34	29	85.3	22	81.5
Unprofitable	48	28	58.3	13	50.0

In Table VIII is a comparison of the annual repairs reported by the two classes of owners under consideration, together with the total repairs. In this connection it should be noted that a number of the men who reported the total amount of repairs for their tractors did not report the repairs by years. The total repairs, therefore, do not agree exactly with the sum of the annual repairs.

Considering Tables IV to VIII as a whole, it is seen that the greatest differences existing between the averages for the two classes of owners represented are those between the estimated life of the tractor in years, the average amount of time lost per day, and the repairs. These items show that decidedly better results are being obtained by the men who state that the tractor is a profitable investment, as they lost considerably less time per day on account of engine trouble, had much lower repair charges, and, in their opinion, they will obtain approximately one more year's service from their tractors than the men who believe the tractor is unprofitable.

TABLE VIII.—*Annual repairs for tractors on farms in North Dakota and other States west of the Mississippi River.*

[Arranged according to the opinions of owners as to the tractor's desirability as an investment.]

IN THE STATE OF NORTH DAKOTA.

Result of investment as reported by owners.	First year.		Second year.		Third year.		Fourth year.		Average total repairs.[1]	
	Amount.	Percentage of value.	Amount.	Percentage of value.	Amount.	Percentage of value.	Amount.	Percentage of value.	Amount.	Percentage of value.
Men having had one season's experience:										
Profitable	$26.33	1.1							$26.33	1.1
Unprofitable	72.54	2.9							72.54	2.9
Men having had two seasons' experience:										
Profitable	21.29	.8	$64.00	2.4					96.68	3.7
Unprofitable	69.53	2.7	144.55	5.7					229.49	9.0
Men having had three seasons' experience:										
Profitable	32.70	1.3	87.39	3.4	$91.83	3.6			198.35	7.7
Unprofitable	81.56	3.1	125.62	4.8	175.35	6.7			359.22	13.8
Men having had four seasons' experience:										
Profitable	16.36	.7	52.23	2.3	85.06	3.8	$71.41	3.1	230.05	10.2
Unprofitable	39.73	1.6	63.29	2.6	91.12	3.8	94.58	3.9	442.52	18.2

IN ALL STATES WEST OF THE MISSISSIPPI RIVER EXCEPT NORTH DAKOTA.

Result of investment as reported by owners.	First year.		Second year.		Third year.		Fourth year.		Average total repairs.[1]	
	Amount.	Percentage of value.	Amount.	Percentage of value.	Amount.	Percentage of value.	Amount.	Percentage of value.	Amount.	Percentage of value.
Men having had one season's experience:										
Profitable	$36.44	1.6							$36.44	1.6
Unprofitable	75.29	3.2							75.29	3.2
Men having had two seasons' experience:										
Profitable	27.43	1.1	$65.95	2.7					101.24	4.2
Unprofitable	60.40	2.5	122.41	4.9					195.41	8.0
Men having had three seasons' experience:										
Profitable	36.46	1.4	77.03	3.0	$71.50	2.8			196.99	7.7
Unprofitable	52.59	2.1	118.81	4.8	137.48	5.5			325.67	13.1
Men having had four seasons' experience:										
Profitable	18.70	.8	43.00	1.9	57.66	2.7	$83.87	3.7	290.57	12.9
Unprofitable	43.48	1.9	93.12	4.0	122.50	5.3	151.87	6.5	424.84	18.3

[1] Many owners reported the total repairs, but did not give them by years. This column is the average of all reports of total repairs, and therefore does not agree exactly with the sum of the annual repairs.

It will also be noticed that the successful owners use their tractor more days annually than do the unsuccessful owners, which would naturally be expected in view of the smaller number of horses kept by the former class of men.

The causes underlying the difference in results obtained are many and various. While much of the difference can be traced to the owner or operator, other important factors are involved, and some of these will be shown in the tables that follow.

GASOLINE AND KEROSENE TRACTORS.

In view of the fact that the groups of owners who gave favorable reports regarding the tractor invariably showed a larger percentage of kerosene tractors than did the groups reporting unfavorably, it was thought desirable to make a comparison of these two types of tractors, in order to ascertain what difference, if any, existed between them. Table IX shows this comparison.

This table was prepared entirely from figures furnished by tractor owners located in North Dakota who had used their tractors for two seasons. This was done for the reason that it was not considered advisable to give too much weight to the reports furnished by men who had used their tractors but one season and were therefore not fully qualified to express reliable opinions. Nor was it considered fair to the tractor to include reports from men who had purchased tractors three or more seasons ago, and who were therefore basing their opinions largely on less efficient models than those now on the market. While the tractors which have been in use for two seasons are not quite so efficient as those sold during 1913, the difference is not so great as exists between the earlier models and those which have been used two seasons.

TABLE IX.—*Comparison of gasoline and kerosene tractors on farms in North Dakota, prepared from reports of owners with two seasons' experience.*

Item of comparison.	Data from owners of tractors.	
	Gasoline.	Kerosene.
Number of tractors reported	127	94
Owners stating that tractor is a good investment ... per cent	28	39
Life of tractor (estimated) ... years	5.9	6.9
Annually used ... days	82	88
Average time spent in the field per day ... hours	13	13
Time lost per day for repairs, etc ... do	2.2	1.9
Average drawbar rating of tractors ... horsepower	24.6	23.0
Average size of farms ... acres	841	866
Number of horses kept:		
Before purchase of tractor	15.8	17.8
After purchase of tractor	11.6	12.3
Average number of horses displaced	4.2	5.5
Owners who do custom work ... per cent	69	74
Owners doing custom work who find it profitable ... do	47	67
Average cost of tractor ... dollars	2,573.00	2,469.00
Average cost of repairs required:		
First season ... do	61.00	33.00
Second season ... do	123.00	81.00
Average value of special equipment purchased ... do	692.00	734.00
Price received per acre for plowing ... do	1.87	1.88
Price received per acre for breaking ... do	3.54	3.56

It is believed that the comparison made in Table IX is the fairest and most reliable which it is possible to make, and a similar method has been used in preparing several of the tables that follow.

From the comparison made, it will be seen that the figures are slightly in favor of the kerosene tractor in almost every case, the

most important differences being in the estimated life and the cost of repairs required annually; but the percentage of replies, days used annually, hours lost, horses replaced, and percentage finding custom work profitable, all of which are favorable to the kerosene tractor, are worthy of note.

While this table shows that the amount of equipment per tractor is greater for the kerosene than for the gasoline tractors, the difference being $42, this figure is really favorable to the kerosene tractor, as it is shown in Table X that the kerosene tractor pulls a greater cross section of plows, etc., than does a gasoline tractor of equal rating. It will, therefore, require a larger gang to provide a full load, and consequently the cost of the equipment is slightly higher.

Table X presents a comparison of the operating factors for gasoline and kerosene tractors of 15 and 30 horsepower, drawbar rating. These figures were furnished by men in North Dakota with only one year's experience and are therefore probably slightly more favorable to the tractor than would be the case if the owners were men of longer experience. The reason for using figures furnished by men with only one season's experience is the fact that among the reports for tractors which had been used for two seasons there were very few for gasoline and kerosene tractors of exactly the same ratings for which complete information had been furnished. While the number of these machines among the 1-year-old tractors is not large, it is believed to be sufficient to insure a fairly reliable comparison.

TABLE X.—*Comparison of results obtained on farms in North Dakota with gasoline and kerosene tractors during their first season's use.*

Item of comparison.	Drawbar ratings of tractors.			
	15 horsepower.		30 horsepower.	
	Gasoline.	Kerosene.	Gasoline.	Kerosene.
Number of tractors reported	28	24	41	27
Plowed per hour ... acres	1.4	1.5	2.1	2.3
Depth plowed ... inches	5.9	6.2	6.1	6.3
Width of plow ... do	77.1	80.6	110.8	123.3
Width of harrow drawn at same time as plows ... do	98.1	102.9	96.3	107.7
Distance traveled per hour ... miles	2.1	2.1	2.3	2.2
Fuel used per day ... gallons	33.0	44.0	57.9	66.5
Cost of fuel used per day ... dollars	6.41	5.50	10.26	8.78
Cylinder oil used per day ... gallons	2.5	3.3	4.1	4.6
Cost of cylinder oil used per day ... dollars	.91	1.29	1.69	1.84

Table X shows that the acres plowed per hour, the depth plowed, width of plow, and width of harrow are all greater for the kerosene than for the gasoline tractor. The amount of fuel consumed is greater for the kerosene tractor, but the cost is less, on account of the lower price per gallon. Both the amount and value of the lubricating oil used are greater for the kerosene tractor, however.

FUEL SUPPLY.

The showing made by the kerosene tractors in comparison with those burning gasoline is of special interest in view of the comparatively recent introduction and development of the kerosene tractor. A few years ago the supply of gasoline could not be increased rapidly enough with the distilling systems then in use to meet the requirements of the thousands of gasoline engines of all kinds being manufactured. As a consequence, the price of gasoline gradually increased.

The engine manufacturers, therefore, fearing that the rise in the price of gasoline would hurt the sale of their product, devoted their efforts to developing an engine which would burn the heavier and cheaper oils. At the same time the oil refiners bent their efforts toward developing a process which would produce a larger quantity of the lighter fuels from the crude oils. Both have apparently accomplished their purpose. Engines are now on the market which apparently handle the heavier fuels with even better results in some respects than are obtained from the engines burning gasoline, while the oil refiners can now vary the quality of petroleum products at will.

On account of a misunderstanding which seems to be quite general as to the present status of the fuel resources of this country, a short discussion of the subject will be of interest.

There seems to be a rather prevalent opinion that the supply of fuel oil is rapidly nearing exhaustion, that the percentage of the lighter fuels, especially gasoline, which can be obtained from the crude oil, is growing less, and that the price of gasoline will therefore soon increase to such an extent as to prohibit its use in farm engines. Statements to this effect are quite common and frequently appear in print. While appearances may have indicated such a condition a few years ago, recent developments in the petroleum industry prove that such statements have no foundation in fact at the present time.

In the opinion of Dr. David T. Day, of the United States Geological Survey, the known oil supply of this country will in all probability be sufficient for the next 100 years. Dr. Day has been in charge of the petroleum investigations of the Geological Survey for a number of years and is qualified to speak with authority on this subject. As to the percentage of gasoline that can be obtained from the crude oils, Dr. Day, in a recent address before the Franklin Institute, spoke as follows:

> This consideration naturally suggests the vital question of an adequate gasoline supply. Even if we produce 25,000,000 barrels of gasoline in the next year this would probably be too little for a year or two of further automobile progress.

The means for meeting the demand are in sight. * * * In the first place, recent developments in knowledge of the resources of the United States make it probable that there will be no great decline in oil production in the future; therefore no decline in gasoline supply is likely. As to the necessary increase, this will come from synthetic gasoline obtained from petroleum itself.

Several years ago I found that if these oils are distilled under pressure the yield of gasoline is still greater, and that the unpleasant odor, due to deficiency in hydrogen in the composition of the oils, can be remedied by actually combining hydrogen with the oil in the still under the influence of a catalytic agent. Recently the demand for any kind of gasoline has waived the requirement of good odor, and other processes are producing much synthetic gasoline.

By such means, low-grade residues have been made to yield from 20 to perhaps 70 per cent of their weight in material which will serve as gasoline.

The "low-grade residues" of which Dr. Day speaks in the last paragraph quoted are the oils from which the regular amount of gasoline has been distilled under the old processes. Under the new process probably 75 per cent of nearly all of the crude oils may be converted into gasoline.

It is therefore safe to assume that the price of gasoline will not advance in the next few years because of scarcity, for sufficient gasoline can be readily produced to meet all requirements. In other words, the oil-refining industry has reached a stage where the quantity of any petroleum product may be increased or diminished at will, to meet the requirements of the trade; that is, if the demand for gasoline increases and that for kerosene decreases, part of the raw product which in the past has been distilled into kerosene will be converted into gasoline instead.

The heavier oils possess more heat units per gallon, but practically the same per pound as the lighter ones. The more heat units a given quantity of fuel contains, the more power it should develop; therefore, if the heavier products could be as readily burned as the lighter ones they should command a higher price per gallon. The heavier fuels present difficulties in starting the engine when cold, however, usually requiring it to be run for a short time on a lighter fuel until it becomes hot enough to handle the heavier one satisfactorily. Recent improvements in design promise to overcome this objection.

FUEL CONSUMPTION.

The consumption of fuel per hour by tractors of different ratings is shown in Table XI. According to these figures, the amount of fuel consumed per hour varies from about $3\frac{1}{5}$ gallons for the 20-horsepower tractor to $5\frac{3}{4}$ gallons for the 30-horsepower outfit during the first year. For the 2-year-old tractors the range is from $3\frac{1}{7}$ to about $6\frac{1}{3}$ gallons per hour. In five out of the seven groups the amount is greater for the second year than for the first, which would seem natural, as after wear has commenced in the motor the fuel consumption will not be so economical.

While the figures in Table XI would appear to indicate that the consumption of fuel per drawbar horsepower is considerably greater for the small tractors than for the large ones, Table XIV shows that the small tractors are usually loaded more nearly to their full capacity than the large ones, and the consumption of fuel per unit of work done is slightly less for the 12 and 15 horsepower tractors than for those of 30 horsepower.

TABLE XI.—*Average consumption of fuel per hour by different sizes of engines and per drawbar horsepower hour on farms in North Dakota.*

Fuel consumption per hour.	Drawbar rating of engine (horsepower).						
	12	15	20	22	25	30	40
First year:							
Per engine.........gallons..	3.264	3.462	3.211	5.419	4.725	5.761	5.684
Per drawbar horsepower.........do....	.272	.231	.161	.246	.189	.192	.142
Second year:							
Per engine.........do....	3.854	4.177	3.140	5.885	5.858	5.675	6.367
Per drawbar horsepower.........do....	.321	.278	.157	.268	.234	.189	.159

There appears to be considerable irregularity in the figures shown, but this is not really the case, as the reasons for the varying consumption for the different sizes are as follows: The 15, 22, and 30 horsepower groups all contain a larger percentage of kerosene tractors than the 12, 20, 25, and 40 horsepower groups, and, as has already been shown, the kerosene tractors consume a greater quantity of fuel than the gasoline tractors. There are also more kerosene tractors in the 12-horsepower group than in the 20, and several of the outfits included in the 20 and 25 horsepower groups are apparently overrated, to judge both by their fuel consumption and by the amount of work done, as shown in other tables.

The fuel cost per unit of work varies, of course, with the price per gallon. The prices for the different fuels vary considerably in different States. The averages of those reported are shown in Table XII. The general averages per gallon for the four fuels commonly used were as follows: Distillate, 8.17 cents; kerosene, 10.08 cents; motor spirits, 15.86 cents; gasoline, 18.94 cents. The distillate and motor spirits are not extensively used, as the table shows.

TABLE XII.—*Average prices for fuels, per gallon, as reported by farm tractor owners.*

State.	Gasoline.	Kerosene.	Motor spirits.	Distillate.
	Cents.	*Cents.*	*Cents.*	*Cents.*
Montana	22.99	15.37		
North Dakota	19.51	11.79	16.53	
South Dakota	18.47	9.86	14.39	
Nebraska	18.06	9.44		
Minnesota	17.72	9.31		
California	17.50			8.29
Texas	17.50	9.90		6.25
Missouri	17.00	7.90		
Kansas	16.23	7.78		
Average	18.94	10.08	15.86	8.17

LUBRICATING OIL.

The quantity of lubricating oil required is another question of considerable importance in connection with the operation of a tractor. The average consumption per hour for tractors of different ratings is shown in Table XIII. The increase in the amount of oil consumed shows closer relation to the increase in the horsepower of the tractor than did the fuel, although there are some irregularities, most of which are explained by the remarks in connection with Table XI. The price per gallon for lubricating oil not only varies in different sections, but varies according to quality. The prices paid per gallon range from 25 to 60 cents, the average price being about 40 cents.

TABLE XIII.—*Average consumption of cylinder oil per hour for different sizes of farm engines and per drawbar horsepower hour.*

Cylinder-oil consumption per hour.	Drawbar rating of engine (horsepower).						
	12	15	20	22	25	30	40
First year:							
Per engine........................gallons..	0.168	0.267	0.291	0.302	0.325	0.401	0.424
Per drawbar horsepower............do....	.014	.0178	.0145	.0137	.013	.0134	.0106
Second year:							
Per engine........................do....	.280	.282	.276	.408	.302	.338	.477
Per drawbar horsepower............do....	.0233	.0188	.0138	.0185	.012	.0112	.0119

The figures shown include all lubricating oil used, whether for cylinders or other purposes, but do not include the cost of greases. This is a comparatively small item, and it is difficult to obtain figures for it.

CROSS SECTION OF PLOWS DRAWN AND AREA PLOWED BY TRACTORS.

The cross section of plows drawn by tractors of different ratings is given in Table XIV, showing that the area of the cross section of plows drawn by the different sizes of tractors bears a close relation to the quantity of fuel used. In this table it will also be seen that the 20 and 25 horsepower outfits do not pull plows commensurate with their ratings, to judge by the loads drawn by the other tractors. Attention is invited to the remarks made in connection with Table XI regarding the rating of tractors in the 20 and 25 horsepower classes and the percentage of gasoline and kerosene tractors in the remainder (p. 22). The area of the cross section of plows drawn by the tractors which have been used two seasons is generally less than the area the first season. There are several possible explanations of this, but the most probable one is believed to be that before the end of the second season many owners have learned that it does not pay to overload a tractor.

Table XIV also shows the average number of acres plowed per hour by tractors of different ratings on farms in North Dakota. These

figures show a close relation to the cross section of the plows, as given in the upper half of the same table. The irregularities already noted in the case of the 20 and 25 horsepower tractors also occur. In five out of the seven classes of tractors there is shown a slight decrease in the amount of work done per hour by the tractors which have been used two seasons.

TABLE XIV.—*Average area of the cross section of plows drawn and area plowed per hour in North Dakota by different sizes of farm engines.*

Plows and plowing.	Drawbar rating of engine (horsepower).						
	12	15	20	22	25	30	40
Area of cross section of plows drawn:							
First year—							
Per engine.....square inch..	447.21	474.86	474.69	716.86	625.37	726.68	908.92
Per drawbar horsepower.....do....	37.27	31.66	23.73	32.58	25.01	24.22	22.72
Second year—							
Per engine.....do....	464.62	459.43	455.81	662.72	665.03	736.03	748.68
Per drawbar horsepower.....do....	38.72	30.60	22.79	30.12	26.60	24.53	18.71
Area plowed per hour:							
For 1-year-old tractors—							
Per engine.....acres..	1.248	1.410	1.405	1.946	1.637	2.175	2.374
Per drawbar horsepower.....do....	.104	.094	.070	.088	.065	.073	.059
For 2-year-old tractors—							
Per engine.....do....	1.386	1.350	1.327	1.753	1.926	2.028	2.165
Per drawbar horsepower.....do....	.116	.090	.066	.080	.077	.068	.054

While these averages are in harmony with the other figures regarding the operating factors, attention is invited to the fact that an average amount of work for a tractor in North Dakota may be either a great deal more or a great deal less than for some other section where conditions are different. There are so many factors which influence the amount of work which can be accomplished with a tractor that average figures are of use only in the section from which they were obtained or under conditions almost identical. The figures for North Dakota represent, for the most part, extremely favorable conditions for tractor plowing.

BREAKING.

The conditions which obtain in breaking sod, are even more various and produce wider variations in the amount of work done than those which are found in plowing.

The number of reports on breaking received from any one section was too small to merit publication of the averages obtained from them. In North Dakota, where the sod is broken with comparative ease and where there is little brush to interfere, the average acreage broken per hour varied from about eight-tenths of an acre for the 12-horsepower tractors to 1½ acres for the 30 and 40 horsepower tractors.

Many men report the same acreage per day in breaking as for plowing, as the breaking is not done so deep as plowing and the tractor wheels find a better grip. In most cases, however, the acreage broken per day is only about two-thirds of that plowed.

COMBINATION WORK.

The percentage of tractor owners who reported combination work with their tractor, i. e., performing two or more operations at one time, such as plowing and harrowing, was much smaller than might have been expected. The figures in connection therewith for the States of North Dakota, South Dakota, Iowa, and California are shown in Table XV. From this it would seem that combination work is practiced considerably less in the semiarid regions than in the more humid sections, although the total number of owners who attempt other operations than plowing and harrowing at the same time is very limited.

There are several reasons for this lack of combination work. Usually there is not much excess power available for other implements if the plow is the full width of the tractor, and, too, additional implements require more attention and this frequently causes more delays, a stop for one implement meaning a stop for the entire outfit.

TABLE XV.—*Use of farm tractors for combination work in the States of North Dakota, South Dakota, Iowa, and California.*

Number reported.	State.	Using plows only.		Using plows and harrows.		Using plows, harrows, and drills.	
		Number.	Per cent.	Number.	Per cent.	Number.	Per cent.
	Men having one season's experience:						
266	North Dakota	155	58.3	106	39.8	5	1.9
82	South Dakota	47	57.3	35	42.7	0	....
82	Iowa	19	23.2	63	76.8	0	....
44	California	10	22.7	34	77.3	0	....
	Men having two seasons' experience:						
262	North Dakota	140	53.4	118	45.1	4	1.5
59	South Dakota	30	50.9	29	49.1	0	....
34	Iowa	4	11.8	29	85.3	1	2.9
27	California	6	22.2	20	74.1	1	3.7
	Men having three seasons' experience:						
124	North Dakota	68	54.8	52	42.0	4	3.2
39	South Dakota	19	48.7	18	46.2	2	5.1
17	Iowa	4	23.5	13	76.5	0	....
15	California	2	13.3	12	80.0	1	6.7
	Men having four seasons' experience:						
55	North Dakota	22	40.0	32	58.2	1	1.8
38	South Dakota	19	50.0	18	47.4	1	2.6
9	Iowa	5	55.6	4	44.4	0	....
0	California	0	....	0	....	0	....

But the principal reason is probably the fact that it is difficult to have the implements follow each other in proper alignment, especially on curves and at corners, which causes poor work to be done. This is especially true in drilling, and most farmers prefer to do this work with horses in order to have it done properly. The harrowing is not so important, as ground missed by it does not so materially affect the crop and does not show after the crop has grown. There is a distinct advantage in the case of many soils in having the harrowing done promptly, yet it appears, considering the four States as a whole, that only about 52 per cent of tractor owners pull harrows with the plows.

DEPTH OF PLOWING.

In order to ascertain whether plowing is usually deeper when done by tractor than when done by horses, Tables XVI and XVII were prepared. Table XVI shows the average depths of tractor plowing in nine States for the number of seasons for which reliable averages could be obtained. While the variations seem to be slight, they are greater than would appear at first glance. Each depth shown represents an average of a large number of reports, most of which are, of course, close to the final average; therefore, in order to increase or diminish the final average even one-tenth of an inch requires a general increase or decrease in the individual reports.

TABLE XVI.—*Average depth of tractor plowing on farms in various States.*

State.	Average depths reported (inches).				State.	Average depths reported (inches).			
	First season.	Second season.	Third season.	Fourth season.		First season.	Second season.	Third season.	Fourth season.
North Dakota	6.18	5.88	6.14	6.11	Iowa	6.35	6.42		
South Dakota	6.47	6.44	6.57	6.58	California	6.85	6.77		
Kansas	6.30	6.47	6.50		Nebraska	6.71	6.02		
Minnesota	6.21	5.87	5.55		Texas	6.19			
Montana	6.19	6.17	6.09						

The distribution of the individual reports for all States west of the Mississippi River is shown in Table XVII. The concentration of the reports on the 5, 6, and 7 inch depths will be seen. The reports for the second season show a decided decrease in the percentage reporting 7 inches or more, with a corresponding increase for 6 inches or less. In the third and fourth seasons there appears to be a gradual return to the greater depths, but in connection therewith it must be borne in mind that the men who have used tractors for three or four seasons have been the most efficient operators; in fact, they are the survival of the fittest, for the first two seasons serve to eliminate many of the inefficient operators, as well as many of the defective outfits.

TABLE XVII.—*Percentage of tractor plowing done at various depths on farms in all States west of the Mississippi River.*

Depth of plowing.	First season.	Second season.	Third season.	Fourth and subsequent seasons.	Depth of plowing.	First season.	Second season.	Third season.	Fourth and subsequent seasons.
4 inches	3.84	4.94	5.17	5.94	8 inches	11.54	7.84	11.72	8.22
5 inches	16.85	23.51	20.34	14.61	9 inches	2.72	1.60	3.45	.91
6 inches	37.22	41.66	36.55	41.10	10 inches	2.04			5.94
7 inches	24.32	18.72	20.34	21.46					

While no averages showing the depth of plowing done by horses which are entirely comparable with those shown in Tables XVI and XVII are available, a comparison of these averages with such averages as were available for horse plowing indicates that the difference in depth of plowing, if any exists, is rather in favor of the horse.

The reason for so little deep plowing with the tractor is very evident upon a slight examination into the matter. Most tractors are incapable of pulling a plow cutting the full width of the tractor and turning more than a 6-inch furrow under ordinary conditions. Therefore, if deeper plowing is to be done the gang must be decreased in width, i. e., one or more plow bottoms must be raised, when the gang will no longer cut out the full width of the tractor's track, which will probably result in the tractor's wheels passing over the same ground twice, causing excessive packing of the soil.

But the greatest difficulty is that the gang plow which is not as wide as the tractor must be hitched to one side of the longitudinal center of the machine, in order to permit the drivewheels to travel on the unplowed land. Such a hitch not only makes the tractor difficult to steer, but exerts a twisting strain on the tractor's frame, which is conducive to short life and heavy repair charges. If such a plow is hitched to the center of the tractor, one drivewheel must travel on the plowed land in order to bring the plow close enough to the land side, thus requiring more power to propel the tractor and making steering difficult.

Most tractor owners, therefore, prefer to use a gang plow wide enough to permit its being attached to the center of the tractor frame and at the same time allow the drivewheels to travel on the unplowed land, regulating the depth of the plow by the amount of power available.

PACKING SOIL BY TRACTORS.

With the early steam tractors the packing of the soil by the tractor's wheels often caused serious injury to the crop.

This feature of the early tractor was much advertised and caused considerable prejudice in the minds of many farmers against all tractors, both gas and steam.

While some gas tractors, under certain conditions, have injured the crop by packing the soil, this is not ordinarily the case. The answers of 135 tractor owners who were personally interrogated on this point have been compiled. These men were located in various States in the Northwest. In answer to the question "Does the packing of the soil by tractor wheels injure the crop?" only 9 men state that the packing of the soil is injurious, while 101 say that it is not, 22 of this number declaring it to be beneficial. Of the 135 owners answering, 25 replied: "If the soil is wet, yes; if dry, no."

It may be safely stated that on most soils, when they are in fit condition to be worked satisfactorily with horses, the modern gas tractor will cause no injurious packing. The slippage of the tractor's wheels in soft ground will probably be a more serious matter than the packing.

COMPARISON OF DIFFERENT SIZES OF TRACTORS.

Table XVIII was prepared in order to ascertain what influence the size of the tractor has on the results obtained with it. In this table the tractors working in the State of North Dakota have been shown separately from those in other States, and only figures furnished by men having two seasons' experience have been shown, for reasons already given.

In tabulating the data by sizes of tractors it was found advisable to group them to a certain extent, in order to have a sufficient number in each class to give reliable averages. They were accordingly arranged in five classes, as follows: (*a*) 8 to 14 horsepower, (*b*) 15 to 19 horsepower, (*c*) 20 to 25 horsepower, (*d*) 26 to 30 horsepower, and (*e*) 40 horsepower and over.

These classes were arbitrarily arranged so as to place a considerable number in each group and at the same time to keep the most common sizes in separate classes. The average rating of the tractors in each group is shown in the table. Thus, the 8 to 14 horsepower class includes three common sizes: 8, 10, and 12, although there is not a very large number of any of these sizes. The 15 to 19 horsepower class consists almost entirely of 15 horsepower tractors. The 20 to 25 horsepower class includes three common sizes: 20, 22, and 25, but, like the first class, none of these sizes has a very large number. The 26 to 30 horsepower class contains 30-horsepower tractors almost exclusively. No machines with drawbar ratings between 30 and 40 horsepower were reported, and the tractors in the fifth class are mostly 40-horsepower outfits, as very few larger sizes were reported.

From this tabulation it would appear that the 15-horsepower tractors have a longer life than those of other sizes. The length of life seems to decrease slightly with the increase in size of tractors over 15 horsepower, while for the smaller sizes it is a little less than for the 15-horsepower tractors. The larger sizes of tractors lose more time per day than those of 15 horsepower or less, the loss increasing with the size of the tractor. The amount of special equipment required increases with the size of the tractor until the 30-horsepower size is reached. The amount of special equipment for the 40-horsepower tractor is less than for those of 30 horsepower. Previous tables have shown that the amount of work done by the 40-horsepower tractor, as well as the load drawn, is not commensurate with its rating, but no reason is known why the value of its equipment should be less than for the 30-horsepower tractor.

TABLE XVIII.—*Comparison of tractors of different sizes, which have been used for two seasons on farms in North Dakota and other States west of the Mississippi River.*

IN THE STATE OF NORTH DAKOTA.

Item of comparison.	Drawbar rating of engine (horsepower).				
	Less than 15.	15 to 19.	20 to 25.	26 to 30.	40 and over.
Number of tractors reported	20	34	105	99	21
Average drawbar rating of engines......horsepower..	11.6	15.0	21.2	30.0	40.7
Cost of engine......dollars..	2,010.16	1,928.92	2,360.41	2,902.05	3,153.25
Cost of special equipment......do....	457.08	557.36	714.72	836.56	826.95
Life of tractor (estimated)......years..	6.2	7.0	6.4	6.6	5.0
Used per year......days..	57.1	88.3	85.1	85.9	61.1
Time spent in the field per day......hours..	12.4	13.4	12.9	13.0	12.7
Time lost in the field per day......do....	2.7	2.3	2.1	2.0	2.4
Average size of farms......acres..	622.2	613.9	792.6	995.2	1,156.0
Horses now kept:					
Number	10.4	9.2	11.3	13.6	17.3
Value......dollars..	1,834.72	1,381.78	1,883.80	2,259.54	2,706.57
Fuel used in engines:					
Gasoline......per cent..	66.7	20.6	67.5	49.4	92.9
Kerosene......do....	33.3	79.4	28.9	45.6	7.1
Motor spirits......do....	0	0	3.6	5.0	0
Cost of repairs required:					
First season......dollars..	30.64	33.58	44.63	52.67	105.59
Second season......do....	75.85	84.71	103.10	122.25	102.32
Owners stating that tractor is a good investment......per cent..	13.3	39.1	30.8	38.0	18.7
Reporting night work......do....	0	18.2	17.1	16.9	5.6
Average nights used by men reporting night work...	....	22.0	16.4	22.7	6.0
Owners doing custom work......per cent..	70.6	75.8	65.4	73.7	61.9
Men doing custom work who find it profitable, per cent	40.0	70.8	48.2	63.9	38.5

IN ALL STATES WEST OF THE MISSISSIPPI RIVER EXCEPT NORTH DAKOTA.

Item of comparison.	Less than 15.	15 to 19.	20 to 25.	26 to 30.	40 and over.
Number of tractors reported	60	73	153	107	41
Average drawbar rating of engines......horsepower	10.8	15.1	21.7	30.0	40.4
Cost of engine......dollars..	1,654	1,820	2,356	2,876	3,616
Cost of special equipment......do....	281.35	461.05	600.61	763.56	719.23
Life of tractor (estimated)......years..	8.9	9.1	8.1	7.2	6.8
Used per year......days..	75.4	88.9	83.6	86.3	122.9
Time spent in the field per day......hours..	11.1	11.6	12.2	11.7	11.5
Time lost in the field per day......do....	1.5	1.5	1.8	1.8	1.9
Average size of farms......acres..	397	563	576	875	1,246
Horses now kept:					
Number	7.9	9.9	8.9	10.8	13.5
Value......dollars..	1,147.02	1,540.54	1,420.10	1,758.42	2,242.50
Fuel used in engines:					
Gasoline......per cent..	69.8	12.3	58.4	57.3	88.2
Kerosene......do....	30.2	86.2	40.0	41.7	5.9
Motor spirits......do....	0	1.5	1.6	1.0	5.9
Cost of repairs required:					
First season......dollars..	23.36	13.92	35.54	41.34	97.54
Second season......do....	40.01	33.05	93.25	75.88	207.68
Owners stating that tractor is a good investment......per cent..	47.0	64.8	43.9	43.9	62.5
Reporting night work......do....	6.5	17.5	19.0	17.2	45.5
Average nights used by men reporting night work....	8.3	20.7	28.2	36.8	54.1
Owners doing custom work......per cent..	56.1	72.9	74.1	75.7	80.0
Men doing custom work who find it profitable, per cent	75.0	78.3	66.3	54.3	67.9

It will be noticed that the 15-horsepower tractors have the lowest repair charges, those for the 40-horsepower tractors being more than seven times as great as for the 15-horsepower outfits. A larger percentage of owners of 15-horsepower tractors than of any other size report that the tractor is a good investment. The next largest percentage of favorable reports is from the 40-horsepower class, while the percentage of favorable reports from the intermediate classes is considerably below those for the 15 and 40 horsepower groups.

These facts, together with others shown in the tables, seem to indicate that the 15-horsepower tractor is giving better average results than any other size. It will be seen that the 15-horsepower tractors also give more favorable operating figures than any other size of tractor.

While the figures for the different sizes of tractors in Table XVIII show other variations, it is believed most of them are due to causes other than the size of tractor. For example, the number of horses kept, the percentage of night work done, and the percentage of custom work done, increase with the size of the tractor, but this increase is probably due largely to the fact that the larger tractors are usually found on the large farms, as will be noticed by the average sizes of the farms shown in the table.

SIZE OF FARM.

In North Dakota, tractors are seldom found on farms of less than 320 acres, the average size of the farm on which tractors are used in that State being between 700 and 800 acres. In other States, particularly in Iowa, tractors are frequently found on farms as small as 160 acres. As will be seen from Table XIX, however, a very large percentage of tractor owners do custom work with the tractor, indicating that the home farm does not furnish sufficient work to keep the tractor busy during the entire working periods. It will also be noticed that the farms ot less than 480 acres show a greater percentage of owners doing custom work than do those of larger size.

Table XIX was prepared in order to ascertain what effect the size of the farm had upon the results obtained from the tractor. The figures used in its preparation are those furnished by tractor owners in North Dakota who have used their outfits for two seasons. A similar table for other States was not made because of the many types of farming which would be represented, as it was believed the many and varying factors involved would vitiate the results obtained. In North Dakota, however, as has already been stated, the conditions are very similar throughout the State, and the averages in the table are believed to show the relation of the size of the farm to the results obtained, as far as it is possible to do so.

In this connection, attention is invited to the fact that there is a close relation between the size of the tractor and the size of the farm, the larger tractors usually being found on the large farms. In both the tabulation by size of farm and by size of tractor, therefore, it is impossible to determine to just what extent each of these factors influences the result.

From the table it would appear that slightly better results are being obtained on the larger farms. It will be noticed that the percentage of owners reporting that the tractor is a good investment is greatest

for the farms of more than 640 acres, although it will also be observed that these men show a rather high percentage of kerosene tractors, which may be partly responsible for this, as well as other favorable averages for the larger farms.

While the estimated life of the tractor is slightly higher for the small farms, it should be borne in mind that these farms for the most part have comparatively small tractors, especially the 15-horsepower size, and this tractor shows a high average life in Table XVIII.

There is no appreciable difference in the number of days used per year, which would indicate that the smaller farms not only have a greater percentage of owners who do custom work, but that the amount of custom work per farm is also greater.

TABLE XIX.—*Relation of the size of the farm to the results obtained with tractors.*

Item of comparison.	Size of farms (acres).				
	161 to 320.	321 to 480.	481 to 640.	641 to 1,000.	1,001 to 2,000.
Number of farms reported	25	33	58	83	55
Average size of farms ... acres	300.2	424.2	583.2	846.4	1,411.5
Owners stating that tractor is a good investment, per cent	10.0	30.8	22.2	39.7	40.0
Drawbar rating of engine ... horsepower	20.0	22.5	22.8	25.0	27.4
Cost of engine ... dollars	2,286.19	2,497.72	2,416.49	2,579.45	2,730.56
Cost of special equipments ... do	624.98	641.18	635.04	766.59	799.37
Cost of repairs required:					
First season ... do	30.89	20.47	50.49	58.01	59.62
Second season ... do	106.74	82.28	90.01	82.84	177.04
Horses now kept:					
Number	5.7	6.9	9.0	11.6	19.2
Value ... dollars	957.73	1,135.88	1,427.59	2,004.75	3,100.57
Life of tractor (estimated) ... years	7.3	7.1	6.0	6.3	6.6
Used per year ... days	80.8	78.3	79.1	86.8	77.1
Time spent in the field per day ... hours	13.2	12.3	12.9	13.3	12.7
Time lost in the field per day ... do	2.4	2.1	2.0	2.3	2.2
Fuel used in engines:					
Gasoline ... per cent	47.8	71.9	58.7	49.2	44.2
Kerosene ... do	47.8	25.0	39.1	45.9	55.8
Motor spirits ... do	4.4	3.1	2.2	4.9	0
Reporting night work ... per cent	15.8	14.3	14.0	11.9	19.6
Average nights used by men reporting night work	13.0	12.8	13.0	14.1	33.2
Owners doing custom work ... per cent	79.2	84.8	64.9	78.5	46.4
Men doing custom work who find it profitable, per cent	56.2	48.1	36.7	67.9	61.9

The percentage of owners who use their tractor at night is greatest for the farms of 1,000 to 2,000 acres, and these men likewise use their tractors for the greatest number of nights per year. From this fact it would appear that only on the larger farms is there sufficient work to utilize the full capacity of the tractor during the busy season, and even on these large farms more than 46 per cent of the owners do custom work.

As would be expected, the cost of the tractor increases with the size of the farm, owing, of course, to the increase in the size of the outfit. The repair charges and value of special equipment likewise increase with the size of the farm for the same reason. But while the cost of special equipment undoubtedly bears a close relation to the size of the

tractor, the investment cost per acre is of great importance. Table XIX shows that on the smaller farms of approximately 300 acres the cost per acre for mechanical power is about $7.60, while on the larger farms, averaging about 1,400 acres, the cost per acre is less than $2. Similarly, while the small farms show an investment of about $2 per acre for special equipment, the large farms have only one-fourth this amount.

In this connection, the value of work horses per acre should also be noted. For the 300-acre farms the cost for work stock is about $3 per acre, while for the 1,400-acre farms it is only $2 per acre.

Especial attention is invited to the difference in the ratio of the investment cost per acre for the two kinds of power. For mechanical power the investment per acre for the small farms is more than 3½ times as great as for the large farms, while for animal power it is only 1½ times as great.

The reason for this difference is probably the fact that a stable of horses, consisting of a number of individual units, can be regulated in size to meet actual requirements, the price per unit being practically uniform no matter in what number purchased. On the other hand, the tractor is a complete unit and must be of sufficient power to fulfill the maximum demands which may be made upon it, while the cost per horsepower is greater in the small sizes than in the large ones. In other words, the owner of a 600-acre farm who purchases a 30-horsepower tractor will have a lower investment per acre for power than the owner of a 300-acre farm who purchases a 15-horsepower tractor, because the 15-horsepower tractor costs more per horsepower than the 30-horsepower outfit; while the owner of a 600-acre farm who purchases one work horse for each 30 acres of land, or 20 horses, will have the same investment charge per acre as the owner of a 300-acre farm who purchases one work horse for each 30 acres of land, or 10 horses, the cost per horse being nearly the same, no matter in what number purchased.

From Table XIX it will be seen that the total investment per acre for power on the 300-acre farms is about $10, while for the 1,400-acre farms it is only $4 per acre, although the 300-acre farms have a unit of power for every 12 acres, while the 1,400-acre farms have one unit for every 32 acres. It is evident, therefore, that either the 300-acre farms have more power per acre than is necessary and economical or that the 1,400-acre farms have an inadequate amount of power.

From a careful study of the data shown, in conjunction with other information available, it is believed that the large farms have a normal acreage per unit of power and that farms of the grain type which have a smaller acreage per horsepower are overequipped and therefore less economically equipped. The owner of a 300-acre farm who has an invested capital of $10 per acre for power and one unit of power for

every 12 acres can not hope to produce crops as cheaply as his neighbor with a 1,400-acre farm who has an invested capital of only $4 per acre and who tills 32 acres with each unit of power.

It is not surprising, therefore, that the owners of farms containing 640 acres or less do considerably more custom work than those with larger farms, as the excess power must produce some income in order to justify its maintenance.

In this connection, it should also be noted that the repairs per acre are considerably less for the large farms than for the small ones, which naturally follows, in view of the difference in equipment. It is probable that the repairs bear a closer relation to the size of the engine than to the size of the farm, in view of the slight difference in the number of days used.

USE OF TRACTORS AT NIGHT.

The number of men who used their tractors at night was found to be surprisingly small (about 11 per cent in North Dakota and 14 per cent in other States) and in most cases the number of nights used per year was comparatively insignificant. While the tractor is theoretically capable of working night and day, it appears that night work is seldom done.

The explanation of this probably lies in the fact that in normal years there is little need for operating at night, unless it be during harvest, when it may be desirable to rush the work as much as possible in order to prevent loss from storms. However, tractors are not extensively used for harvesting except in those sections where it is practicable to use a combined harvester. Another reason for the small amount of night work is the necessity of having two operating crews for the outfit. This is obviously impractical in most cases.

In order to ascertain whether any loss of efficiency occurs when operating at night, a number of tractor owners who had operated at night were asked for estimates as to the percentage of efficiency compared with work done in the daytime. The average of these estimates was 93.3 per cent.

This slight loss in efficiency appears to be due almost entirely to inability to watch the operation of the outfit as well as it can be done during the day and the additional time required to make any adjustments which may be necessary.

Among some 70 men who were interrogated regarding night work the opinion was almost unanimous that the motor developed more power at night than during the day, some estimating the increase to be as much as 20 per cent.[1]

[1] This information was voluntary, the men having been asked simply for an estimate as to the efficiency of the tractor at night. They offered their observations as to the increase of power at night as a phenomenon which they could not explain. In view of the varying opinions of gas-engine experts on this point, the unanimous observation of tractor operators that such an increase does occur is of interest.

CUSTOM WORK.

In order to ascertain what difference, if any, existed between the figures furnished by men who did custom work with their tractors and found it profitable and those who did custom work but did not make it pay, Table XX was prepared. From this it would appear that the principal factors which operate to make custom work unprofitable are the time lost by the engine and repair charges, which are, of course, closely related, as making repairs and replacing parts take considerable time. It will also be noticed that the men who say that custom work does not pay show slightly less investment in equipment in each case, although not sufficiently less to draw any definite conclusions therefrom.

Little difference exists in the prices received per acre for custom work by the men who report it profitable and those who find it unprofitable, which would seem to indicate that this factor had little influence on the result. This, together with the fact that nearly 50 per cent of the tractor owners who have tried custom work state that it is unprofitable, would seem to justify the assumption that the prices received for custom work, namely, about $2 per acre for plowing and $3.70 per acre for breaking, are very close to the actual average cost of performing this work, assuming that the cost for fuel, oil, interest charges, etc., were the same for each class of owners, which would probably be the case.

TABLE XX.—*Comparison of figures furnished by farm tractor owners in North Dakota who had done custom work.*

[Columns headed "Yes" include figures from men who stated that custom work was profitable; those headed "No" include figures from men who stated that custom work was unprofitable.]

Item of comparison.	First season.		Second season.		Third season.		Fourth season.	
	Yes.	No.	Yes.	No.	Yes.	No.	Yes.	No.
Number answering	118	40	92	72	44	38	20	15
Average drawbar rating of tractor ... horsepower	23.8	23.2	24.5	24.5	24.3	25.1	22.6	22.9
Average price of tractor, dollars	2,525.36	2,460.85	2,563.70	2,557.19	2,615.68	2,694.41	2,376.32	2,431.00
Average time lost in the field, hours	1.4	1.9	1.5	2.4	1.9	2.8	1.7	2.9
Average cost of repairs, dollars	33.60	68.09	88.03	249.87	197.35	411.00	227.49	681.74
Average value of equipment, dollars	648.23	636.78	733.16	721.70	761.34	748.64	756.50	745.73
Average size of farm ... acres	730.2	796.0	804.9	708.4	692.8	806.2	682.3	820.0
Average price per acre received for plowing ... dollars	1.97	1.80	1.91	1.91	2.03	2.21	2.03	2.08
Average price per acre received for breaking ... dollars	3.66	3.48	3.68	3.46	3.71	3.71	3.81	3.68

In this connection it should be noted that very few farmers in figuring the cost of performing work of this character take into consideration interest and depreciation charges, which previous tables have shown to be very heavy for the average tractor.

REPAIRS.

The cost of repairs has always been an item of considerable importance in connection with the farm tractor. Not only have the repairs been expensive, but the time lost in obtaining new parts and inserting them has been a serious matter.

This feature has frequently been pointed out as one of the greatest disadvantages of the tractor and one which practically precludes its use on the average farm.

It is only fair to the tractor, however, to state that a very large percentage of the repairs are made necessary through inefficient operation. The statement that any man can operate a gas tractor efficiently after only a few minutes' instruction is so far from the truth that it would seem that its falsity should be apparent to even the uninitiated. Yet this erroneous idea has been responsible for hundreds of failures and an enormous amount of repair charges, the effect of which has been detrimental to the tractor industry. If every man who used a tractor during the years of its development had been thoroughly competent to operate it, the history of the farm tractor would be very different.

While the average farmer's familiarity with many machines and their operation should make him an apt pupil in the study of the gas tractor, it is in no sense a complete education therein. There are many tractor owners at the present time who, while operating their tractor with a certain degree of satisfaction, are unfamiliar with many details of its mechanism; in fact, it is the exception to find a tractor owner who fully understands one of the most important parts of the tractor—the ignition system.

It is this ignorance regarding details, some of them apparently trifling, which all too frequently causes expensive delays. An internal-combustion engine is extremely simple in its operation, but it is simple only to one who understands it fully. No one but an experienced operator can obtain the best results with a farm tractor, and the necessity for an owner carefully studying the principles of the internal-combustion engine and the operation of his own tractor before undertaking to operate the outfit can not be overemphasized. The lack of such preparation is clearly shown in the cost of repairs to tractors during their first season's use. As has been stated, although in nearly every case all repairs required the first season which are not caused by the operator are furnished free, it was found that the repairs for which owners are required to pay during the first season average about 2 per cent of the first cost of the tractor.

While previous tables have shown the amount of repairs for various groups of tractors, it was thought a table showing the general average repairs for tractors might be of value. It would be mani-

festly unfair to the modern tractor to consider repairs on outfits placed on the market several years ago, while the repairs required during the first season on tractors of one, two, and three years of age do not vary to any great extent, and Table XXI was prepared to show the repairs on tractors up to three years of age. The repairs required on tractors located in North Dakota and California have been shown separately, while the remaining States west of the Mississippi River are grouped.

It will be noticed that the repairs for tractors in California are much heavier than for the other States. This is due mainly to the difference in the types of tractors most generally used, a large percentage being of the track-laying type. These are usually more expensive outfits, as will be seen from the table.

These figures show that during the first season, when all repairs not caused by the operator are ordinarily furnished free, the average tractor owner spends for repairs an amount varying from 1.7 to 4 per cent of the tractor's cost.

TABLE XXI.—*Tractor repair charges per year, with percentage of first cost, on farms west of the Mississippi River.*

Range of inquiry.	Average price of tractor.	First season.		Second season.		Third season.	
		Average repairs.	Percentage of cost.	Average repairs.	Percentage of cost.	Average repairs.	Percentage of cost.
For 1-year-old engines:							
North Dakota	$2,465	$44.86	1.8				
California	3,181	127.18	4.0				
Other States	2,279	38.94	1.7				
For 2-year-old engines:							
North Dakota	2,542	49.37	1.9	$107.15	4.2		
California	3,620	142.37	3.9	306.68	8.5		
Other States	2,361	34.66	1.5	72.89	3.1		
For 3-year-old engines:							
North Dakota	2,590	62.17	2.4	108.44	4.2	$138.39	5.3
California	3,604	150.13	4.2	186.50	5.2	220.50	6.1
Other States	2,430	43.62	1.8	104.09	4.3	98.24	4.0

During the second season the repair charges show a variation between 3.1 per cent and 8.5 per cent of the tractor's cost, while for the tractors which have been used three seasons the percentage is more favorable, varying from 4 to 6.1 per cent.

From this it would appear that a prospective purchaser of a tractor should expect during the three seasons' use repair charges of at least 10 per cent of the first cost.

The repair charges given throughout this bulletin include only the cost of the new parts. The cost of installing these parts is often considerable, but it is sometimes done by the tractor owner and sometimes by hired machinists. It is therefore difficult to ascertain the value of the labor expended in making the repairs.

DISPLACEMENT OF HORSES BY TRACTORS.

It is difficult to determine to just what extent the tractor has influenced the use of horses on the farm, on account of the other influencing factors in the shape of automobiles, motorcycles, autotrucks, and binder engines, all of which are doing work formerly done by horses. In spite of all these competitors the farm horse has increased considerably in numbers and value during the past few years.

The United States Census report shows that in 1900 there were 11,513,649 horses and mules on farms located in States west of the Mississippi River, while the Bureau of Statistics of the United States Department of Agriculture states that on January 1, 1914, they numbered 14,287,000, a numerical gain of 2,773,351, or 24.1 per cent in 14 years.

During the same period the increase in the valuation of these animals was much greater, viz, from $493,454,902 to $1,427,074,000, or 189.2 per cent; but here again there were numerous influencing factors, the principal ones probably being a heavy export demand and the breeding of horses of a far better quality.

The gains mentioned occurred while the number of gas tractors was increasing from less than 100 to perhaps 13,000.

A comparison of the increase in the number of farm horses and of tilled acres in the States west of the Mississippi River would be desirable, but accurate figures on the increase in tilled acres are not available, and, furthermore, improvements in farm implements and in the management of farms have tended to increase the acreage tilled per horse.

A study of the conditions existing on farms where tractors have been introduced is of especial interest in this connection. The result of such a study is shown in Table XXII.

The data contained in this table were obtained by personally visiting the tractor owners. The records for the farms represented were selected without reference to the number of horses displaced, the only point which was considered in selecting them being to ascertain whether the information furnished was complete. Therefore, the fact that of the number thus selected 39 belonged in the group where horses were displaced by the tractor and 43 in the group where no horses were displaced by the tractor would seem to be a rather reliable indication that in about 50 per cent of the cases the tractor does not actually displace horses on farms where it is introduced.

These farms average approximately 900 acres in size and should therefore provide a large amount of work for the power employed, whatever its kind. They are mostly of the grain type, exceptionally well adapted for the use of a tractor. The average age of the tractors

is less than two years, which shows that for the most part they are very modern outfits. The tractor did not entirely displace the horses on any farm.

TABLE XXII.—*Displacement of horses by tractors on farms.*

Item of comparison.	Farms on which horses were— Displaced.	Farms on which horses were— Not displaced.	All farms.
Number of farms	39	43	82
Average size of farm ... acres	924	875	896
Average area tilled per farm ... do	844	661	748
Average number of horses per farm:			
Before purchase of tractor	25.3	13.2	18.9
After purchase of tractor	8.8	13.2	11.1
Average number of horses displaced per farm	16.5	....	7.8
Value of horses displaced per farm ... dollars	3,115.86	....	1,423.89
Average value per horse ... do	188.84	176.10	182.55
Average drawbar rating per farm ... horsepower	26.1	24.3	25.1
Average cost of tractor ... dollars	2,635.00	2,775.00	2,702.00
Total present rating per farm ... horsepower	34.9	37.5	36.2
Average area tilled per drawbar horsepower of tractor ... acres	32.3	27.2	29.8
Average area tilled per horse:			
Before purchase of tractor ... do	33.4	50.0	39.5
After purchase of tractor ... do	95.9	50.0	67.3
Average area tilled per total horsepower after purchase of tractor ... do	24.2	17.7	20.5
Average age of tractors ... years	1.8	1.9	1.9
Average use of tractor per year ... days	94.5	120.2	101.6
Cost of maintaining a horse per year (estimated) ... dollars	84.09	105.56	96.81
Average price of fuel per gallon ... do	.147	.185	.167
Average price of oil per gallon ... do	.423	.388	.405

While the value of special equipment which would be required with the tractor is not shown here, from previous tables it is evident that the value of such equipment would not be less than $700 per farm; therefore, on more than 50 per cent of the included farms the purchase of the tractor increased the invested capital approximately $3,500 and on the remainder the horses displaced would lack about $300 of equaling the value of the tractor and its necessary equipment.

On the farms where horses were displaced, the tilled acreage per horse before the purchase of a tractor was 33.5, which is believed to be about the normal area. Although the acreage per drawbar horsepower of the tractor on these farms was only 32.3, yet an average of 8.7 horses per farm was retained, making the tilled acreage per unit of power 24.2 acres. On the other hand, the tilled acreage per horse on the farms where horses were not displaced was 50 acres, and the tilled acreage per drawbar horsepower of the tractor purchased was 27.2 acres, or an average of 17.7 tilled acres per unit of total horsepower. The tilled acreage per total horsepower for both of these groups would appear to be too small for the most economical operation.

In Table XXIII are shown some further data relative to the displacement of horses by tractors. This table was prepared from figures furnished by tractor owners in North Dakota who had used their tractors for two seasons.

TABLE XXIII.—*Displacement of horses on farms in North Dakota where tractors have been used for two seasons.*

Item of comparison.	Farms on which no horses were displaced.	Farms on which horses were displaced—drawbar rating of engine (horsepower).		
		20 or less.	21 to 29.	30 or over.
Number of farms reported	82	40	16	29
Average number of horses used:				
Before purchase of tractor	16.6	13.8	15.9	20.7
After purchase of tractor	16.6	8.4	9.2	12.1
Horses displaced:				
Average number		5.4	6.7	8.6
Average value ....dollars		891.56	1,202.92	1,489.35
Average cost of tractor ....do	2,543	2,020	2,665	3,000
Average drawbar rating of tractor ....horsepower	24.1	18.1	22.9	31.2
Value of special tractor equipment ....dollars	720	556	743	803
Cost of repairs required:				
First season ....do	43.34	46.36	37.00	80.49
Second season ....do	115.64	83.33	43.29	125.25
Owners stating that tractor is a good investment ....per cent	10.3	37.5	53.3	52.4
Life of tractor (estimated) ....years	5.4	6.2	7.4	7.3
Used per year ....days	60.3	98.0	106.5	90.0
Time spent in the field per day ....hours	12.7	13.3	13.0	13.2
Time lost in the field per day ....do	2.7	1.9	2.4	1.9
Fuel used in engines:				
Gasoline ....per cent	57.6	69.4	28.6	47.6
Kerosene ....do	39.4	27.8	64.3	47.6
Motor spirits ....do	3.0	2.8	7.1	4.8
Average size of farm ....acres	940	662	779	1,024
Owners doing custom work ....per cent	52.4	78.9	75.0	85.2
Men doing custom work who find it profitable ....do	37.8	51.9	60.0	72.2
Reporting night work ....do	9.4	26.7	18.2	18.2
Average nights used by men reporting night work	31.5	25.4	17.5	17.3

While the percentage of farms on which horses were displaced is greater than for Table XXII, this is explained by the fact that many tractor owners in filling out the form on which the information was furnished gave only the number of horses used after the purchase of the tractor, the space for the number previously kept being left blank. It is very probable that many of these were intended to indicate that the number was the same, but in the absence of positive information on this point the data were not tabulated.

On these farms the number of horses displaced is considerably less per farm than for those shown in Table XXII. In no case is the value of the horses displaced equal to 50 per cent of the first cost of the tractor.

There appears to be little difference in the results obtained by the two classes of owners. The most significant variations seem to be found in the percentage of owners who report that the tractor is a good investment, the percentage doing custom work, and the percentage doing night work. In these three cases the men who did not lay off horses after purchasing the tractor show much lower percentages than those who report that horses were displaced by the tractor.

CONDITIONS ESSENTIAL TO SUCCESS WITH THE TRACTOR.

The fact that some men have found the tractor a profitable investment is proof that under certain conditions it can be used successfully for farm work.

The physical condition of the land determines largely the degree of success which can be obtained with a tractor. The ideal conditions are large, level fields, free from obstructions, such as trees, stumps, rocks, holes, and ditches, with a soil firm enough to furnish a solid footing for the drive wheels, yet not sufficiently hard to make an excessive draft on the plows.

But the most important qualification is efficient management and operation. This has been touched upon, but can not be overemphasized. For the operator to be able to start and stop the motor and to steer the outfit skillfully is not enough. He must understand his tractor thoroughly, and not only be able to locate quickly any trouble which occurs and remedy the same promptly, but he must be capable of avoiding a great many of the troubles commonly experienced with tractors, by frequent inspection of the bearings, ignition system, etc., thus keeping them in first-class condition at all times.

Not only in the actual operation of the tractor does the efficient tractioneer contribute to the success of the outfit, but by carefully studying the work to be done and planning it so as to allow the tractor to work to the greatest advantage at all times. If the land is rolling he will so lay out his work that the tractor will ascend on the easiest grades and descend on the steepest. If the farm is laid out in square or irregular fields he will replan it so as to have the fields as long as possible, thus lessening the number of turns which will be required. He will fill in holes and ditches where practicable and remove obstructions in order to facilitate the tractor's work. He will recognize the fact that work can not be done with a tractor in exactly the same manner as with horses, and to attempt to do so is not only unfair to the tractor but is inviting failure. In many cases a change in crop rotation will be of great advantage. Where a tractor is used the crops raised should be such as can be planted and harvested with the tractor, thus reducing the number of horses which must be kept.

The necessity of having tractor owners properly trained for the operation of their outfits has been recognized by most manufacturers, and several have established schools for their customers where they can be instructed by experts in the care and operation of the tractor. The tractor salesmen have also realized that in selling outfits to men who are incompetent to operate them they are not only injuring their own interests, but those of the tractor trade in general.

A number of agricultural colleges have added courses in tractioneering, and there are several privately conducted tractor schools. It is believed that most farmers who contemplate purchasing a tractor would find it well worth while to take a short course in tractioneering

at some one of these schools. It will be time and money well spent. The knowledge gained will be of great assistance in selecting a tractor, as well as in operating it. The time and money which the course requires will be saved in many cases during the first two seasons.

Another important factor in determining the success or failure of a tractor is the amount of capital invested in it. The average farmer can not afford to increase his power investment to any great extent. In purchasing a tractor he should not, therefore, spend as much for it as he can realize on the horses it will displace, for the reason that the working life of a tractor is only about half that of a horse, while there are many operations for which the tractor can not be used. The first cost of a tractor should on that account be correspondingly less. It is unsafe to rely on an increase of crops from better work with the tractor, as in most cases this is not realized.

It is significant that many farmers who have bought second-hand tractors at low prices have been very successful with them. It is also significant that the sales of the larger and more expensive outfits have fallen off, while those of the smaller and comparatively cheap ones have largely increased. While there have been numerous influences which combined to produce this result, there is a sound economic reason for it. The average farmer is not only conservative, but he realizes that he can not afford to increase his investment in power too much. While the cost of fuel and oil per unit of power is less than the cost of feed for horses, the overhead charges, due to interest on investment, depreciation, repairs, etc., more than offset this on the expensive outfits, except under conditions unusually favorable to the use of the tractor.

By reducing the first cost the interest and depreciation charges are correspondingly reduced, and it is to be supposed that the cost of repair parts will be proportionate to the first cost. It is apparent that the price of tractors has been too high in the past to permit the average farmer to use them successfully. The indications at present point to a general reduction in the price of these outfits and an increased sale as the price is lowered.

With a decrease in the price of farm tractors and an increase in their mechanical efficiency, simplicity, and durability, all of which seem to be assured, together with more efficient operation by men who have been properly trained for their work, it is safe to predict that the tractor will soon become an important factor in reducing the cost of crop production on the average farm.

SUMMARY.

While the data included in this bulletin represent the experience of a large number of users of gas tractors, it must be borne in mind that they are a record of a machine in the process of development

and not the record of a completed and perfected outfit. Furthermore, most of these tractors have been operated by men who were not properly trained and equipped to handle them efficiently, and during the first few years of the development of the gas tractor the machines placed on the market were mainly large outfits, which were necessarily expensive, and failure meant a heavy financial loss.

It is generally recognized that the gas tractor was of great value in rapidly breaking up large areas of prairie sod in the West at a time when horses were not available, but after the sod was broken they proved an unprofitable investment for the individual farmer in a large percentage of cases. A few owners have found the tractor a very profitable investment, doing its work more satisfactorily and much cheaper than could be done with horses, while a great many discontinued its use after a trial.

The percentage of owners reporting favorably regarding the tractor decreases with the length of time they have used their outfit, due partly to the fact that the older machines were not as good as the later ones, but mainly to a better realization of the tractor's value in their work.

As would be expected, owners who report unfavorably regarding the tractor obtain poorer average results than those who state that the tractor is a good investment. The repair charges reported by both classes of owners indicate that this is due to a considerable extent to less efficient operation by the owners reporting unfavorably.

The average life of a tractor as estimated by owners in North Dakota is about six years, while the average life as estimated by owners in States other than North Dakota is about eight years. To judge by the small percentage of reports received for tractors three or more years old, it would appear that a large number of outfits three, four, and five years old are no longer in use, indicating that the average life is even less than six years.

The plowing done with tractors has been little, if any, deeper than that done with horses.

Combination work is not practiced to a great extent and usually is limited to harrows or drags after the gang plow.

The percentage of tractors which are operated at night is comparatively small, varying from 11 to 14 per cent, although the tractor's efficiency at night is very good.

No injurious packing of the soil is caused by the tractor's wheels if the soil is in proper condition to be worked.

The item of repairs has been one of considerable importance in connection with the use of farm tractors, but the data indicate that a large percentage of such repairs have been caused by inefficient operation.

The necessity for the operator of a gas tractor being thoroughly trained for his work, if a tractor is to prove a success, is obvious. Failure to comply with this requirement has been the cause of many failures.

The tractors which have been operated by kerosene show, as a whole, slightly better average results than those operated by gasoline, indicating that the heavier fuels can be burned at least as satisfactorily as the lighter ones. The amount of kerosene used per unit of work, however, is usually slightly more than for gasoline, which would appear to indicate that the combustion of the kerosene is generally not as perfect as that of the gasoline. This is partly due to the fact that many owners are burning kerosene in tractors equipped with ordinary gasoline carburetors.

The necessity of a tractor being equipped to operate on either heavy or light fuels is not so great as it was a few years ago. Modern processes of refining make it possible to convert approximately 75 per cent of any crude oil into gasoline or heavier fuels, as desired, and it is stated by an excellent authority that the supply of crude oil available is ample for several generations. Therefore, the question of fuel supply need give the tractor owner no concern.

The data apparently show that the tractors with drawbar ratings of 15 horsepower are giving slightly better results than either the larger or smaller sizes.

The tractor has not, as a rule, displaced its equivalent in work horses, as regards either power or value. Its purchase, therefore, usually increased the investment in power, as well as in certain kinds of equipment. The necessity for a large acreage, if the invested capital per acre is to be kept within a safe limit, is very apparent, although in many farming communities a tractor may prove profitable on a small acreage, provided the owner can obtain some lucrative custom work for the tractor when it is not required on the home farm. A great deal of the custom work which has been done with tractors has proved unprofitable to the tractor owner, however.

The modern gas tractor of 10 or more horsepower has thus far, within its limited area of use, proved to be an auxiliary of the farm horse rather than a substitute. When properly handled, it is often of great value in permitting one or two men to perform a large amount of work within a limited length of time. With further development, a lower first cost, and in the hands of a conservative class of farmers who have been carefully trained in their operation, tractors will undoubtedly continue to grow in number and efficiency, extending their field of work into new territory. The heavy demands for power to break new land are practically over, and the growth of the tractor will hereafter be due more to its merit than in the past.

The present trend of the tractor industry points to the development of cheaper and smaller outfits, designed to pull only from two to four plow bottoms.

The studies here presented merely aim to set forth in a broad way tractor conditions as now found on the farm. A study of these data should be made by every farmer contemplating the purchase of a tractor.

Up to the present time the tractor appears to have made for itself no important place in the agricultural economy of this country. In a few limited localities in the West where conditions especially favor its use large tractors are used by some men with apparent profit. The general situation, however, indicates that the large tractor is not to be a factor in increasing farming by extensive methods and on a large scale, for a few years at least. Instead, there are indications that the tractor of the future must make possible more intensive agriculture on farms of moderate size, though the large outfits will probably continue to be used on some of the exceptionally large farms in the West.

It is worthy of note that some of the successful users of tractors were able to reduce the number of their farm horses. This fact suggests that there may be a field for farm reorganization to make possible the economical utilization of the tractor. Such development depends upon the production of a smaller and cheaper outfit, costing considerably less per unit of drawbar power than its equivalent in horses, thus offsetting the difference in their working life. It must be nimble, simple, and absolutely certain in operation when properly handled. Given such an outfit, the average farmer can afford to reorganize his farm work so as to discard one or more teams, and by utilizing the tractor for heavy field work and for driving machinery be able to reduce the cost of crop production.

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BULLETIN No. 175

Contribution from the Bureau of Plant Industry
WM. A. TAYLOR, Chief

Washington, D. C. ▼ April 29, 1915

MUSHROOMS AND OTHER COMMON FUNGI

By

FLORA W. PATTERSON, Mycologist, and VERA K. CHARLES
Assistant Mycologist, Office of Pathological Collections
and Inspection Work

CONTENTS

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By Flora W. Patterson, *Mycologist*, and Vera K. Charles, *Assistant Mycologist*, *Office of Pathological Collections and Inspection Work.*

CONTENTS.

INTRODUCTION.

The desirability of a Government publication for free distribution by the aid of which the amateur collector may distinguish poisonous and edible species of fungi is suggested by the present-day tendency to popularize science, the increased general interest in nature-study subjects, and the special interest manifested in the subject of mushrooms.

The writers make no claim to originality or to the contribution of new and interesting observations on the subject of mycology, but if this bulletin furnishes the amateur collector or nature student with a means of identifying certain common species and differentiating poisonous and edible varieties its purpose will be attained.

The keys to aid in locating the genus or species are only intended and applicable for use with the species described. Questions of relationship are sometimes necessarily sacrificed for the sake of rendering identifications easier for the amateur.

There has been no effort to include the descriptions of a large number of species, but a few have been selected from each of the most familiar genera. The descriptions are brief and plainly written, the object being to mention the salient features or the distinctive characters of a particular fungus and to avoid as far as possible the

use of technical terms or statements which would require for verification the assistance of a compound microscope. By referring to the appended glossary and with the aid of a hand lens, the amateur collector can expect to recognize a large number of the fungi described in these pages.

For some years certain foreign Governments have been endeavoring to teach their citizens the food value of mushrooms. All over France, but especially in Paris, exhibits are given of desirable species. In Rouen during the season, daily lectures, illustrated by many fresh specimens, are prepared for the benefit of the country residents. In the elementary schools of Saxony systematic instruction is given to families and children, and a permanent exhibit of specimens is also maintained.

To judge from the statements of early authors, for many centuries wild mushrooms have been eagerly collected and eaten, especially in Germany, France, and Italy. Perhaps the only recorded voice of absolute protest came from the ancient Hindus, who considered those who ate mushrooms, "whether springing from the ground or growing on a tree, fully equal in guilt to the slayers of Brahmins." Although early history records the use of mushrooms and the high esteem in which they were held by the ancients, it is true that their nutritive value has been greatly exaggerated and is not high and that they are not as life sustaining as meat, in spite of the frequent assertions of enthusiastic mycophagists to the contrary.

The mushroom most commonly grown and employed for canning is *Agaricus campestris*, but not all canned mushrooms are of the cultivated variety. In France there has been established a large business in preserving wild species in that manner, and they have for some time been for sale here. Tons of dried wild mushrooms are also imported from China.

Too emphatic a statement can not be made as to the absolute impossibility of "telling the difference between mushrooms and toadstools" by any of the so-called "tests."

The only way to discriminate between edible and injurious fungi is by studying each species from a botanical point of view. By paying strict attention to certain constant features, as pointed out by an expert, the acquaintance of several species may readily be acquired during each season. It is well to look with suspicion upon every mushroom which is not positively known to be edible. The absolute necessity of eating mushrooms when perfectly fresh can not be too strongly emphasized.

In collecting mushrooms the plants should not be pulled from the ground by the stem, but they should be lifted out of the earth by the aid of a knife or pointed stick. By this means the form of the base of the stem, a feature of great importance in specific identification,

can be determined and the presence or absence of a volva demonstrated. Careful notes of prominent features should always be made at the immediate time of collection, as some characters are extremely transient. If the opinion of an expert is required, such notes should accompany the specimens. If possible, several of each species should be collected in order to show variation. The plants should be separately wrapped in paper, paraffin preferred (not tissue or raw cotton), and all placed in a wooden box if to be sent by mail.

MORPHOLOGICAL STRUCTURE OF MUSHROOMS AND CERTAIN OTHER FUNGI.

The parts common to most mushrooms and certain other fungi are the cap and the stem. The cap, or pileus, is the apical, fleshy part which on its lower surface bears gills in Agaricaceæ, pores in Polyporaceæ, and teeth in Hydnaceæ. The stem, or stipe, is present in many genera and is normally central; but it may be abbreviated or wholly absent, in which case the plant is said to be sessile, or resupinate if attached by the back, and the attachment may be excentric (not centrally attached) or lateral. The shape of the cap is described as umbilicate when it has a central depression, infundibuliform when funnel shaped, and umbonate when it has a central elevation. The margin may be involute (rolled in) or revolute (rolled out), repand (wavy), etc.

The spores, the microscopic bodies analogous to seeds, are developed from the hymenium or spore-bearing tissue, which covers the surface of the gills in Agaricaceæ, covers the teeth in Hydnaceæ, and lines the pores in Polyporaceæ.

The gills, or lamellæ, are the thin, bladelike, radiating structures borne on the lower surface of the cap. Their color is generally determined by the color of the spores. The method of attachment to the stem is various, and they are described as adnate when attached squarely to the stem, adnexed when reaching the stem but not attached by the entire width, free when not reaching the stem, sinuate or emarginate when notched or curved at the junction with the stem, and decurrent when extending down the stem. The gills are said to be attenuate when their ends are narrowed to a sharp point, acute when they terminate in a sharp angle, obtuse when the ends are rounded, arcuate when arched, and ventricose when broadened at the middle.

In the early stages of development the margin of the cap lies against the stipe. In certain genera, as Amanita, Lepiota, Agaricus, and others, a thin veil is present, uniting the margin of the cap and the stem. This structure, known as the veil, consists of fibers growing from the margin of the cap and the outer layers of the stem. It, or a portion of it, may persist as a firm movable or nonmovable annulus (ring), as in the genus Lepiota, or in the form of remnants

attached to the margin of the cap, as present in *Hypholoma appendiculatum.*

The volva, or universal veil, is the term applied to the membranous envelope which in some genera entirely incloses the cap and stem. In certain species it ruptures at maturity, leaving a cup-shaped base, while often a portion adheres to the pileus in the form of warts or scales.

DESCRIPTIONS OF SPECIES.

In this paper the general plan has been to give a description of the class or family, then a key to assist in the identification of the species herein discussed, and lastly descriptions of the individual genera or species. Descriptions of the following species will be found on the pages indicated.

AGARICACEÆ.

The classification for the genera of Agaricaceæ discussed in this bulletin is based upon the color of the spores. It is generally a comparatively easy matter to form an opinion regarding the color of the spores, but if any difficulty is experienced a spore print may be made. The process is very simple, and the results are quite satisfactory. The stem is removed from the specimen from which a print is desired and the cap placed face down on a piece of paper of contrasting color, covering it with a tumbler. When the spores are mature they will fall in radiating lines on the paper. If a permanent spore print is desired, an alcoholic spray of white shellac may be employed. This is prepared by making a saturated solution of white shellac and then diluting it 50 per cent with alcohol.

Key to Agaricaceæ.

WHITE-SPORED AGARICS.

Plants soft or more or less fleshy, soon decaying, not reviving well when moistened:
- Ring or volva or both present—
  - Volva and ring both present.................................AMANITA.
  - Volva present, ring absent.................................AMANITOPSIS.
  - Volva absent, ring present—
    - Gills free from stem.................................LEPIOTA.
    - Gills attached to the stem.................................ARMILLARIA.
- Ring and volva both absent—
  - Stem excentric or lateral.................................PLEUROTUS.
  - Stem central—
    - Gills decurrent—
      - Edge blunt, foldlike, forked........................CANTHARELLUS.
      - Edge thin, stem fibrous outside........................CLITOCYBE.
      - Edge thin, stem cartilaginous outside.............OMPHALIA.
    - Gills sinuate, general structure fleshy.................TRICHOLOMA.
    - Gills adnate[1] or adnexed—
      - Cap rather fleshy, margin incurved when young...COLLYBIA.

[1] See the Glossary, pp. 56 to 58, for definitions of the technical terms.

Plants soft or more or less fleshy, etc.—Continued.
- Ring and volva both absent—Continued.
  - Stem central—Continued.
    - Gills adnate or adnexed—Continued.
      - Cap thin, margin of the cap at first straight, mostly bell shaped.................................MYCENA.
      - Cap fleshy, gills very rigid and brittle, stem stout—
        - Milk present................................LACTARIUS.
        - Milk absent................................RUSSULA.
    - Gills various, often decurrent, adnate or only adnexed, edge thin, thick at junction of cap, usually distant, waxy..HYGROPHORUS.

Plants coriaceous, tough, fleshy or membranaceous, reviving when moistened:
- Stem generally central, substance of the cap noncontinuous with that of the stem, gills thin, often connected by veins or ridges..MARASMIUS.
- Stem central, excentric, lateral, or absent, substance of the cap continuous with that of the stem—
  - Edge of gills toothed or serrate.........................LENTINUS.
  - Edge of gills not toothed or serrate.....................PANUS.
  - Edge of gills split into two laminæ and revolute..........SCHIZOPHYLLUM.

Plants corky or woody, gills radiating..........................LENZITES.

ROSY-SPORED AGARICS.

Stem excentric or absent and pileus lateral ....CLAUDOPUS.

Stem central:
- Volva present, annulus wanting..................................VOLVARIA.
- Volva and annulus absent—
  - Cap easily separating from the stem, gills free..............PLUTEUS.
  - Cap confluent with the stem, gills sinuate..................ENTOLOMA.

OCHER-SPORED AGARICS (SPORES YELLOW OR BROWN).

Gills easily separable from the flesh of the cap:
- Margin of the cap incurved, gills more or less decurrent forked or connected with veinlike reticulations.......................PAXILLUS.

Gills not easily separable from the flesh of the cap:
- Universal veil present, arachnoid................................CORTINARIUS.
- Universal veil absent—
  - Ring present..PHOLIOTA.
  - Ring absent—
    - Stem central—
      - Cap turned in....................................NAUCORIA.
      - Cap not turned in................................GALERA.
    - Stem excentric or none.................................CREPIDOTUS.

BROWN-SPORED AGARICS.

Cap easily separating from the stem, gills usually free..............AGARICUS.

Cap not easily separating from the stem, gills attached:
- Ring present..STROPHARIA.
- Ring absent, veil remaining attached to the margin of the cap..HYPHOLOMA.

BLACK-SPORED AGARICS.

Gills deliquescing, cap thin, ring present in some species...........COPRINUS.

Gills not deliquescing:
- Margin of cap striate, gills not variegated......................PSATHYRELLA.
- Margin of cap not striate, gills variegated......................PANAEOLUS.

AMANITA.

The genus Amanita is easily recognized among the white-spored agarics in typical species or early stages by the presence of a volva and a veil. Young plants are completely enveloped by the volva, and the manner in which it ruptures varies according to the species. The volva may persist in the form of a basal cup, as rings or scales on a bulblike base, or it may be friable and evanescent. The cap is fleshy, convex, then expanded. The gills are free from the stem, which is different in substance from the cap and readily separable from it.

This is a most interesting genus, on account of the great beauty of color and texture of many of its species and the fact that it contains the most poisonous of all mushrooms. While there are some edible species in the genus, the safest policy for the amateur is to avoid all mushrooms of the genus Amanita.

Amanita caesarea. Cæsar's mushroom.

Cap ovate to hemispherical, smooth, with prominently striate margin, reddish or orange becoming yellow; **gills** free, yellow; **stem** cylindrical, only slightly enlarged at the base, attenuated upward, flocculose, scaly below the annulus, smooth above; **ring** membranaceous, large, attached from its upper margin; **stem** and **ring** normally orange or yellowish, in small or depauperate specimens sometimes white; **flesh** white, yellow under the skin, and usually yellow next to the gills; **volva** large, distinct, white, saclike.

Cap $2\frac{1}{2}$ to 4 or more inches broad; stem 3 to 5 inches long. (Pl. I, fig. 1.)

This species is variously known as Cæsar's agaric, royal agaric, orange Amanita, etc. It has been highly esteemed as an article of diet since the time of the early Greeks. It is particularly abundant during rainy weather and may occur solitary, several together, or in definite rings. Although this species is edible, great caution should always be used in order not to confound it with *Amanita frostiana*, which is poisonous. The points of difference of these two species are conveniently compared as follows:

Species.	Cap.	Gills.	Stem.	Volva.
Amanita caesarea..	Orange, smooth, occasionally with a few fragments of volva as patches.	Yellow............	Yellow............	White, sometimes breaking up into soft, fluffy masses.
Amanita frostiana.	Yellow, smooth or with yellowish scales.	Yellow or tinged with yellow.	White or yellow...	Yellow, sometimes breaking up into fluffy, yellow fragments.

Amanita muscaria. The fly Amanita. (Very poisonous.)

Cap globose, convex, and at length flattened, at maturity margin sometimes slightly striate; **flesh** white, sometimes yellow under the pellicle; remnants of the **volva** persisting as scattered, floccose, or rather compact scales, color subject to great variation, ranging from yellow to orange, or blood red, **gills** white or yellowish, free but reaching the stem; **stem** cylindrical, at first stuffed, later hollow, upper part torn into loose scales, bulb prominent, generally marked by concentric scales forming irregular ridges; **ring** typically apical, lacerated, lax, large.

Cap 3½ to 5½ inches broad, stem 4 to 6 inches long. (Pl. I, fig. 3; from V. K. Chesnut.)

Amanita muscaria may be found during the summer and fall, occurring singly, or in small associations, or in patches of considerable size. It grows in cultivated soil, partially cleared land, and in woods or roadsides. It does not demand a rich soil, but rather exhibits a preference for poor ground. The color is an exceedingly variable character, the plants being brighter colored when young and fading as they mature. The European plant possesses more gorgeous colors than the American form.

This is a very poisonous species, and it has been the subject of many pharmacological and chemical investigations. Its chief poisonous principle is muscarine, although a second poisonous element is believed to be present, as atropine does not entirely neutralize the effect of injections of *Amanita muscaria* in animals.

This species has been responsible for many deaths, and numerous cases of severe illness have been caused by persons mistaking *Amanita muscaria*, the poisonous species, for *Amanita caesarea*, the edible species. While typical specimens of these two species possess distinguishing characters, as already shown, it is again recommended to shun all Amanitæ.

In Siberian Russia the natives make several uses of *Amanita muscaria*. Preserved in salt it is eaten, though probably more as a condiment than as a main article of diet; a decoction is popular as an intoxicant, and deaths are reported upon good authority as resulting from a "muscaria orgy."

Amanita phalloides. Death cup. (Deadly poisonous.)

Cap white, lemon, or olive to umber, fleshy, viscid when moist, smooth or with patches or scales, broadly oval, bell shaped, convex, and finally expanded, old specimens sometimes depressed by the elevation of the margin; **gills** free, white; **stem** generally smooth and white, in dark varieties colored like the cap but lighter, solid downward, bulbous, hollow, and attenuated upward; **ring** superior, reflexed, generally entire, white.

The large, free **volva**, its lower portion closely adherent to the bulb, and the large ring are of assistance in distinguishing this species.

Cap 3 to 4 inches broad; stem 3 to 5 inches long. (Pl. I, fig. 2.)

This species and its forms are subject to great variation in color, ranging from white, pale yellow, and olive to brown. *Amanita phalloides* is a very cosmopolitan plant and one of very common occurrence. It is the most dangerous of all mushrooms, for no antidote to overcome its deadly effect is known. It exhibits no special preference as regards habitat and is found growing in woods or cultivated land from summer to late autumn. When fresh it is without scent, but a peculiarly sickening odor is present in drying plants.

Amanita rubescens.

Cap oval to convex, nearly expanded when old, covered with numerous, unequal, thin, floccose, grayish scales, which are noticeably persistent in dry weather, surface smooth or very faintly striate; **stem** cylindrical, tapering above, bulb prominent, suffused reddish; **ring** membranaceous, large, fragile; **volva** persisting as floccose scales on the cap or present as loose fragments on the bulb.

Cap 4 to 5 inches broad; stem 4 to 5 inches long, about 1 inch thick. (Pl. II, fig. 4.)

This species occurs quite abundantly in the late summer or early fall. It is often found in patches, but it may also appear singly. The European form is sometimes regarded as poisonous, but the American form of *Amanita rubescens* is considered edible. Again the advice to the amateur is to avoid all Amanitae. Dr. W. W. Ford, of Johns Hopkins Hospital, who conducted extensive experiments concerning the poisonous principle in certain Amanitae, states that the American form of this species is not poisonous to man.

FIG. 1.—AMANITA CAESAREA.

FIG. 2.—AMANITA PHALLOIDES. (POISONOUS.)

FIG. 3.—AMANITA MUSCARIA. (POISONOUS.)

FIG. 1.—AMANITA SOLITARIA.

FIG. 2.—GALERA TENERA. (EDIBLE.)

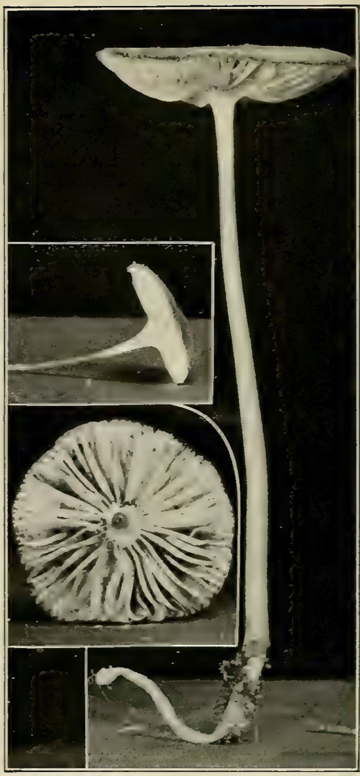


FIG. 3.—COLLYBIA RADICATA. (EDIBLE.)

FIG. 4.—AMANITA RUBESCENS.

FIG. 1.—AMANITOPSIS VAGINATA. (EDIBLE.)

FIG. 2.—AMANITA STROBILIFORMIS.

FIG. 1.—LEPIOTA AMERICANA. (EDIBLE.)

FIG. 2.—CORTINARIUS VIOLACEUS. (EDIBLE.)

FIG. 2.—LEPIOTA NAUCINA. (EDIBLE.)

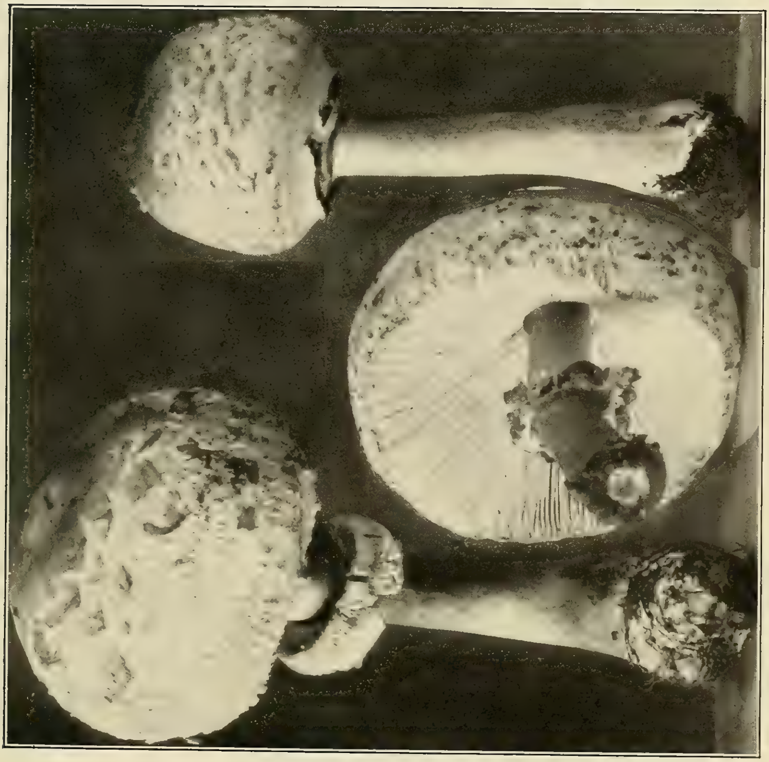
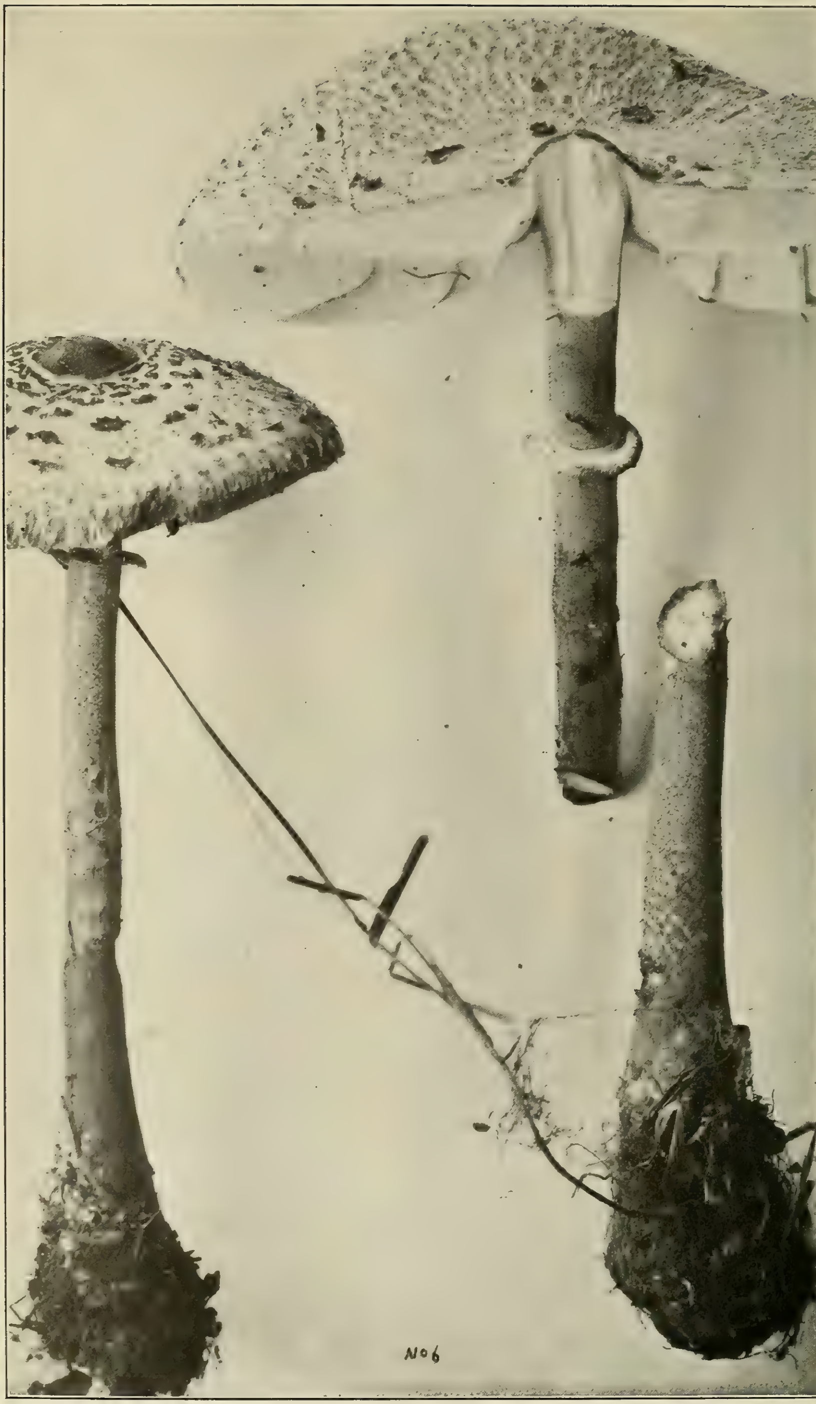


FIG. 1.—LEPIOTA MORGANI. (POISONOUS.)



LEPIOTA PROCERA. (EDIBLE.)

FIG. 1.—PLEUROTUS OSTREATUS. (EDIBLE.)

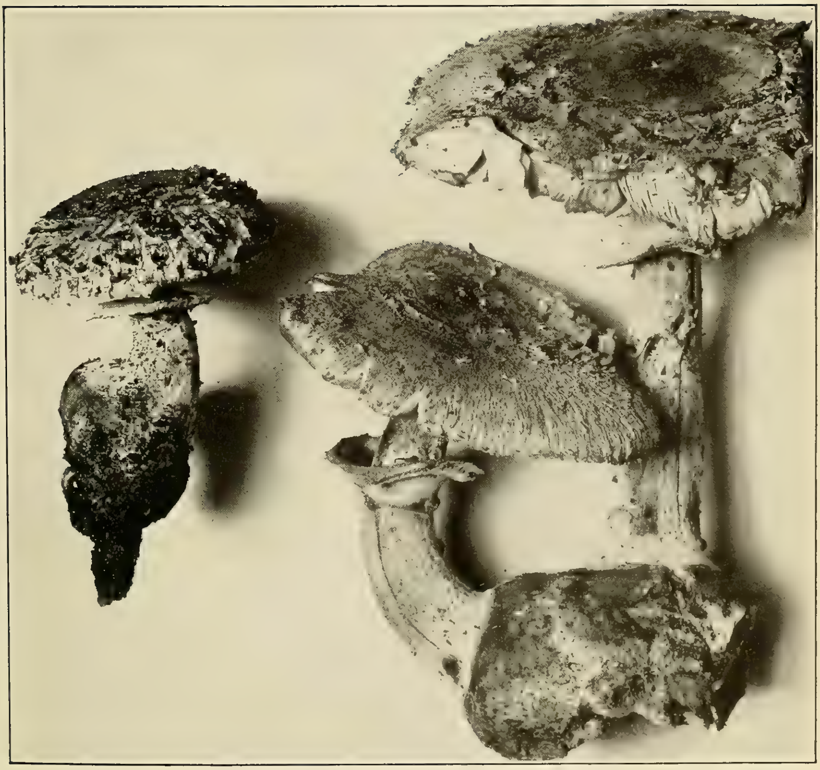


FIG. 2.—LEPIOTA RACHODES. (EDIBLE.)

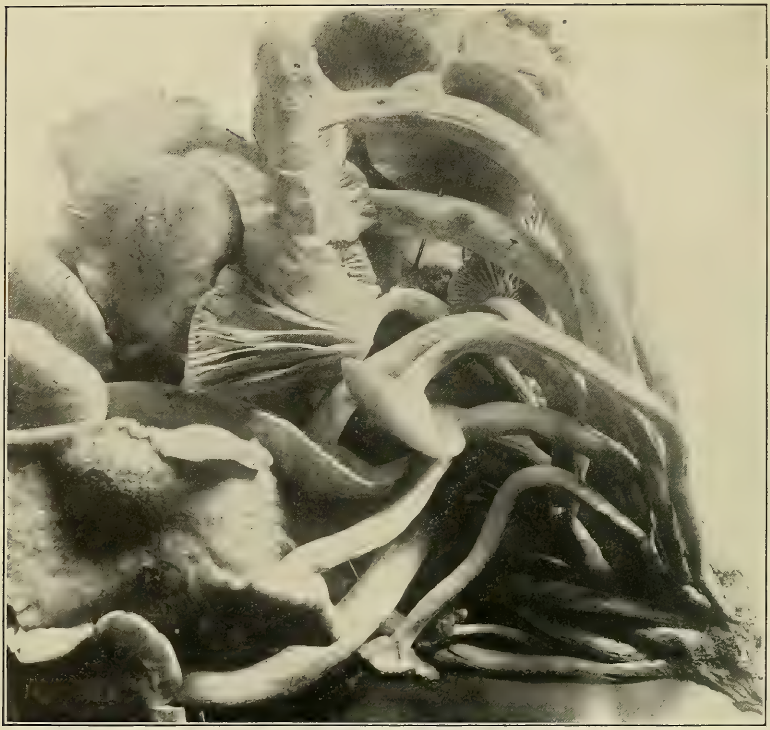


FIG. 2.—CLITOCYBE MONADELPHA. (EDIBLE.)

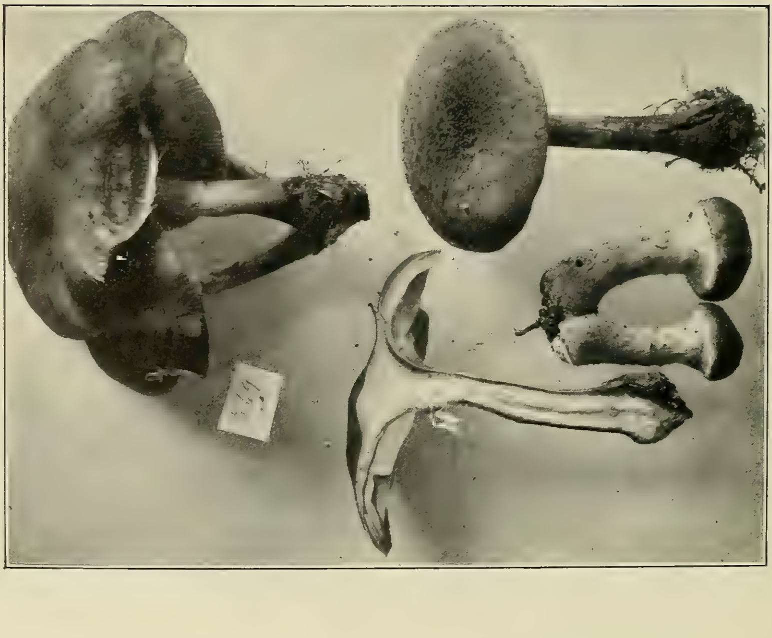


FIG. 1.—ARMILLARIA MELLEA. (EDIBLE.)

Amanita solitaria.

Cap when young hemispherical, later convex to expanded, margin even, somewhat elevated when old, scales flaky or floccose and of a sticky, farinaceous character, easily rubbed off, chalky white; **gills** white or cream, free or attached by only the upper inner angle; **stem** when young mealy or scaly, equal, solid or stuffed, with a bulb of the same character which prolonged into a rootlike process penetrates into the soil a considerable distance; **ring** torn, often adhering as fragments to the margin of the cap and gills; **volva** breaking up into scales which finally disappear.

Cap 3 to 6 inches broad; stem 4 to 6 inches long, one-half to 1 inch thick. (Pl. II, fig. 1.)

A comparative discussion of this species is to be found under *Amanita strobiliformis.*

Amanita strobiliformis.

Cap convex or nearly plane, white, sometimes cinereous or yellowish on the disk, with large angular, pyramidal warts, which are adnate and mostly persistent; margin extending slightly beyond the gills, sometimes bearing fragments of the **ring**, which is large and lacerated; **gills** broad, rounded behind, whitish; **stem** thick, equal or tapering above, solid, floccose scaly, white, bulb very large with concentric-marginate ridges and corresponding furrows, somewhat pointed below.

Cap 3 to 10 inches broad; stem 3 to 8 inches long, 1 to 2 inches thick. (Pl. III, fig. 2.)

There is some uncertainty as to the identity of *Amanita strobiliformis* and *A. solitaria* as they occur in America, but as this bulletin has for its object the popular treatment of the subject, the desire is to call attention to the differences of *Amanita solitaria* and *A. strobiliformis* as generally recognized by the collector and not their systematic position as determined by mycologists. *Amanita solitaria* does not always occur solitary, as its name suggests, but is more readily separated from *A. strobiliformis* by its long rooting base and conic scales than by its method of growth. While these differences are present in typical specimens, it must be remembered that many intermediate forms may occur, thus making the separation of the two species extremely difficult.

Amanita verna. Destroying angel.

Cap white, smooth, viscid when moist, convex then expanded, margin even; **gills** free and white; **stem** stuffed, or hollow in age, bulbous, sheathed at the base by the membranous volva; **ring** reflexed, forming a wide collar.

By most authorities *Amanita verna* is considered a mere form of *A. phalloides,* as it has no constant morphological characters and is only separated by the pure white color and its generally more slender form. Because of its exceedingly poisonous nature it is popularly known as the "destroying angel."

AMANITOPSIS.

By some mycologists Amanitopsis is considered a subgenus of Amanita, from which, however, it differs in the absence of a veil and a ring. The volva is ample and persistent, and the gills are completely free from the stem, which is readily separable from the cap. Great care must be observed in collecting species of this genus for food in order not to collect specimens of Amanita from which the ring has disappeared.

Amanitopsis farinosa. (Edible.)

Cap gray or grayish brown, convex, becoming almost plane or depressed in the center, thin with deeply striate margin, nearly covered with a grayish powder which is readily rubbed off; **gills** whitish, free; **stem** hollow or stuffed, whitish, enlarged at base, subbulbous, with flocculent, pulverulent **volva** which may soon disappear.

Cap 1 to 1¼ inches broad; stem 1 to 2 inches long, 2 to 3 lines thick.

This is an interesting little species of rather infrequent occurrence. The farinose, or mealy, character of the cap is the most striking specific feature. It appears bordering roadsides or in open woods during the summer and early fall months.

Amanitopsis vaginata. (Edible.)

Cap thin and fragile, ovate to bell shaped, or expanded, sometimes umbonate, gray, mouse colored, or brown, smooth, shining, margin deeply striate; **gills** white, free; **stem** smooth or mealy, hollow or stuffed, not bulbous, tapering above; **volva** conspicuous, soft, sheathing but free, often remaining in the ground, being easily separable from the stem.

Cap 1¾ to 4 inches broad; stem 3½ to 7 inches long. (Pl. III, fig. 1; from G. F. Atkinson.)

This is a very common and widely distributed species, occurring from the Pacific to the Atlantic. It is remarkable for great variation in size and color, ranging from 2 to 10 inches broad and varying from gray or umber to tawny. Because of these variations some authorities recognize several varieties.

Amanitopsis vaginata grows in woods, shaded situations, or lawns. It is considered an excellent edible species, but is too easily confused with an Amanita to be recommended for an article of diet.

LEPIOTA.

The genus Lepiota may be distinguished from Amanita and Amanitopsis by the presence of a ring and the absence of a volva. The cap is generally scaly or granular, and the stem is fleshy and easily separable from the cap, in which it leaves a cuplike depression. The gills are usually free and are white when young, but certain species are pink or green when mature. The ring may be fixed or free, and when the plant is young it is readily seen, but before maturity it may have disappeared. The genus contains some of the finest edible species as well as some extremely dangerous ones.

Lepiota americana. (Edible.)

Cap ovate, then convex, expanded, umbonate, the umbo and scales reddish brown; **flesh** white, becoming reddish if cut or bruised; **gills** white, ventricose, close, free; **stem** white, hollow, smooth, swollen near the base; **ring** rather large and delicate, and consequently it may disappear in old age.

Cap 2 to 4 inches broad; stem 2 to 4 inches long, 3 to 5 lines thick. (Pl. IV, fig. 1.)

This mushroom is of wide geographic distribution and grows singly or in clusters, often at the base of stumps, sometimes on sawdust piles, and again on grassy lawns. The plants are white when young, with the exception of the umbo and the scales, but in drying become smoky red. Sometimes they are erect, but frequently more or less ascending. *Lepiota americana* may be easily recognized by the peculiarity of turning red when bruised or old.

Lepiota morgani. Green gill. (Poisonous.)

Cap fleshy, globose when young, expanded to plane or slightly depressed, not umbonate, white with a yellowish or brownish cuticle, which breaks up into scales except in the center; **flesh** white, changing to reddish or yellowish on being cut or bruised; **gills** close, lanceolate, remote, white becoming green; **stem** firm, smooth, hollow, subbulbous, tapering upward, white with brownish tinge; **ring** large, movable.

Cap 5 to 9 or even 12 inches broad; stem 6 to 9 inches long, 4 to 8 lines thick. (Pl. V, fig. 1.)

Great care should be taken to avoid this species. Many instances of poisoning are well substantiated, and extreme inconvenience and serious illness have resulted from eating very small pieces of the uncooked mushroom. The gills are slow in assuming the green tinge characteristic of this species, but after being allowed to remain in ordinary room temperature the color is quite noticeable. This fungus occurs mostly on grassy places, such as lawns and parks, during the summer months, frequently forming large "fairy rings."

Lepiota naucina. Smooth Lepiota.

Cap smooth, rarely minutely scaly, white or smoky, almost globose when young, then convex, expanding, and becoming somewhat gibbous; **flesh** white; **gills** free from the stem, crowded, white, becoming smoky pink when old; **stem** rather stout, enlarged below, nearly hollow or loosely stuffed; **ring** adhering to the stem.

Cap 1½ to 3 inches broad; stem 2 to 3 inches long, 4 to 8 lines thick. (Pl. V, fig. 2; from C. G. Lloyd.)

Prof. Peck describes and discusses a form closely allied to *Lepiota naucina* which he calls *L. naucinoides*, the differences consisting in the smoother cap and the shape of the spores. This latter character, being a microscopic feature, is of no practical assistance to the amateur. These two forms are both edible, but extreme caution must be used in order not to collect poisonous or deadly white Amanitae for specimens of Lepiota before the pink tinge of the gills is apparent.

Lepiota procera. Parasol mushroom. (Edible.)

Cap ovate, then expanded with a distinct, smooth, brown umbo, cuticle early breaking up into brown scales showing the white flesh; **gills** broad, crowded, white, free, and distant from the stem; **stem** tubular, long, bulbous, generally scaly or spotted, its substance distinct and free from the cap, in which a cavity is left by its removal; **ring** large and thick, readily movable when old.

Cap 3 to 6 inches broad; stem 5 to 12 inches long, about 6 lines thick. (Pl. VI; from C. G. Lloyd.)

This very attractive and graceful species may be collected in pastures, lawns, gardens, thin woods, or roadsides. It occurs singly or scattered, appearing during summer and early fall, and is considered an excellent edible species.

Lepiota rachodes. (Edible.)

Cap fleshy, fragile when mature, globose, expanded or depressed, not umbonate, at first covered with a rigid, continuous, bay-brown cuticle, which remains entire at the center, elsewhere reticulated with cracks or separated into loose scales; **flesh** white, quickly changing to saffron red upon being cut or broken; **gills** white, crowded, broad in the center and narrowing toward each end, distant from the stem; **stem** stout, whitish, hollow, smooth in young plant, bulbous; **ring** thick, movable, with scales on the under side.

Cap 2 to 5 inches broad; stem 2 to 4 inches long, about 5 lines thick. (Pl. VII, fig. 2; from C. G. Lloyd.)

This species is closely related to *Lepiota procera*, of which it is sometimes considered only a variety. It differs in its stouter habit, absence of an umbo, and in the changeable flesh, which becomes tinged with red when broken.

ARMILLARIA.

The genus Armillaria is another white-spored agaric having a ring and no volva. The gills are attached to the stem and are sinuate or more or less decurrent. The substance of the stem and cap is continuous and firm. This genus may be distinguished from Amanita

and Lepiota by the continuity of the substance of the stem and cap, and it is further differentiated from Amanita by the absence of a volva. It contains several edible species.

Armillaria mellea. Honey-colored mushroom. (Edible.)

Cap oval to convex and expanded, sometimes with a slight elevation, smooth, or adorned with pointed dark-brown or blackish scales, especially in the center, honey color to dull reddish brown, margin even or somewhat striate when old; **gills** adnate or decurrent, white or whitish, sometimes with reddish brown spots; **stem** elastic, spongy, sometimes hollow, smooth or scaly, generally whitish, sometimes gray or yellow above the ring, below reddish brown.

Cap $1\frac{1}{2}$ to 6 inches broad; stem 2 to 6 inches long, one-half to three-fourths inch thick. (Pl. VIII, fig. 1; from W. A. Kellerman.)

This species is extremely common and variable. It generally occurs in clusters about the base of rotten stumps and is often a serious parasite of fruit trees. Both ring and stem are subject to marked variations. The former may be thick, or thin, or entirely absent, and the latter uniform in diameter or bulbous. The species is edible, though not especially tender or highly flavored.

On account of the great variation in color, surface of the cap, and shape of the stem, several forms of *Armillaria mellea* have been given varietal distinction. The following varieties as distinguished by Prof. Peck may be of assistance to the amateur:

Armillaria mellea var. *flava*, with yellow or reddish yellow cap.

Armillaria mellea var. *radicata*, with a tapering root.

Armillaria mellea var. *albida*, with white or whitish cap.

Armillaria nardosmia. (Edible.)

Cap fleshy, firm and thick at the center, thin toward the margin, whitish with brown spots, cuticle becoming squamulose; **flesh** white; **gills** whitish, crowded, slightly emarginate; **stem** stout, fibrous, sheathed by the brown velvety veil.

Cap about 3 inches broad; stem $1\frac{1}{2}$ to $2\frac{1}{2}$ inches long.

This plant resembles a short-stemmed Lepiota, but is more robust than species of that genus. It is found on the ground in woods, especially in the sandy soil of conifers. Its strong taste and smell of almonds disappear in cooking.

Armillaria ventricosa.

Cap fleshy, convex or nearly plane, smooth, shining white, margin thin and involute; **flesh** whitish; **gills** narrow and close, decurrent, sometimes dentate or denticulate on the edge, whitish; **stem** thick and short, ventricose, abruptly pointed at the base; **ring** lacerated and membranaceous.

Cap 4 to 7 inches broad; stem 2 to 3 inches long, ventricose portion 1 to 2 inches broad. (Pl. IX.)

This is a coarse, conspicuous fungus. It was first described as Lentinus on account of the serrate character of the gills mentioned in the above description. This species was collected in Alabama and described by Prof. Peck in 1896; since that date several collections have been made in the District of Columbia, but it is not generally reported as having a wide distribution.

PLEUROTUS.

The genus Pleurotus is chiefly distinguished among the white-spored agarics by the excentric stem or resupinate cap. The stem is fleshy and continuous with the substance of the cap, but it is subject to great variation in the different species and may be excentric, lateral, or en-

tirely absent. The gills are decurrent or sometimes adnate, edge acute. Most of the species grow on wood, buried roots, or decayed stumps. This genus corresponds to Claudopus of the pink-spored and Crepidotus of the brown-spored forms.

Pleurotus ostreatus. Oyster mushroom. (Edible.)

Cap either sessile or stipitate, shell shaped or dimidiate, ascending, fleshy, soft, smooth, moist, in color white, cream, grayish to brownish ash; **stem** present or absent (if present, short, firm, elastic, ascending, base hairy); **gills** white, decurrent, somewhat distant, anastomosing behind to form an irregular network.

Cap 3 to 5 inches broad; mostly cespitose imbricated. (Pl. VII, fig. 1.)

A very fine edible species, growing on limbs or trunks of living or dead trees, of cosmopolitan distribution, appearing from early summer until late fall.

Pleurotus sapidus. (Edible.)

This species very closely resembles *Pleurotus ostreatus* and is distinguished from it by the lilac-tinged spores, a character difficult or impossible for the amateur to detect. From the mycophagist's point of view, these two species are equally attractive.

Pleurotus serotinus. (Edible.)

Cap fleshy, compact, convex or nearly plane, dimidiate reniform, suborbicular, edge involute, finally wavy, smooth, yellowish green, sooty olive, or reddish brown, in wet weather with a viscid pellicle; **gills** close, distinct, whitish or yellowish, minutely tomentose or squamulose with blackish points.

Cap 1 to 3 inches broad.

In general appearance this fungus resembles *Claudopus nidulans*, but is separated from it by the color of the spores, Pleurotus belonging to the section of white-spored agarics and Claudopus to the rosy-spored species. The plants grow on dead branches or trunks and are gregarious or imbricate.

Pleurotus serotinus is edible but not particularly good, its chief recommendation being the lateness of its occurrence in the fall, when other more tempting species have disappeared.

Pleurotus ulmarius. (Edible.)

Cap fairly regular, although inclined to excentricity, convex, margin incurved, later plane, horizontal, even, smooth, white or whitish, at disk shades of tan or brown; **flesh** white, tough; **gills** broad, rather distant or rounded behind; **stem** more or less excentric, curved, ascending, firm, solid, elastic, thickened, and tomentose at the base.

Cap 3 to 5 inches broad; stem 2 to 3 inches long.

This species occurs abundantly on dead elm branches or trunks or growing from wounds of living trees. Though exhibiting a special fondness for this host, it is not confined to elm trees. It is readily distinguished from *Pleurotus ostreatus* by the long stem and by the emarginate or rounded gills. It is considered an excellent edible species and occurs abundantly in the fall.

CANTHARELLUS.

In the genus Cantharellus the cap is fleshy or submembranaceous, continuous with the stem, and has the margin entire, wavy, or lobed. The gills are decurrent, thick, narrow, blunt, foldlike, irregularly forked, and connected by netlike veins. The two species here discussed are of common occurrence.

Cantharellus aurantiacus. False chanterelle.

Cap fleshy, soft, somewhat silky, shape variable, convex, plane or infundibuliform, margin wavy or lobed, inrolled when young, later simply incurved, dull orange or brownish, especially in the center; **flesh** yellowish; **gills** rather thin, decurrent, forked, dark orange; **stem** spongy, fibrous, colored like the cap, larger at the base than at the apex.

Plant 1 to 3 inches in height; cap 1 to 3 inches broad.

This plant is more slender and the gills are thinner than those of *Cantharellus cibarius*, from which it can be readily distinguished. The taste is generally mild, but sometimes slightly bitter. Foreign and American mycophagists do not agree in regard to the edibility of the species. It is common on the ground or on very rotten logs.

Cantharellus cibarius. The chanterelle. (Edible.)

Cap fleshy, thick, smooth, irregularly expanded, sometimes deeply depressed, opaque egg yellow, margin sometimes wavy; **flesh** white; **gills** decurrent, thick, narrow, branching or irregularly connected, same color as cap; **stem** short, solid, expanding into a cap of the same color.

Plant 2 to 4 inches in height; cap 2 to 3 inches broad. (Pl. X, fig. 2.)

An agreeable odor of apricots may be observed, especially in the dried plants of this species, but its absence need not be construed as affecting the validity of an identification established by other characters. The chanterelle has long been considered one of the most highly prized edible mushrooms. The remark of a foreign mycologist is recalled that "The chanterelle is included when the most costly dainties are sought for state dinners."[1] It is a common summer species found in open woods and grassy places.

CLITOCYBE.

The white-spored genus Clitocybe contains many species, and some of them possess definite generic characters which render identification easy, while others are extremely difficult to recognize. The cap is generally fleshy, later in some species concave to infundibuliform, thinner at the margin, which is involute. The gills are adnate or decurrent. The stem is externally fibrous, tough, not readily separable from the flesh of the cap. The gills in Clitocybe are never sinuate, a character separating it from Tricholoma, with which it agrees in having a fibrous stem.

Clitocybe amethystina. (Edible.)

Cap at first hemispherical, later broadly convex or nearly plane, sometimes depressed in the center and umbilicate, hygrophanous, violaceous when moist, grayish or grayish white when dry, often striate on the margin when young; **gills** violaceous, rather thick, subdistant, adnate or slightly decurrent; **stem** slender, fibrillose, rigid, straight or flexuose, stuffed, later hollow, paler than the moist cap.

Cap 1 to 2 inches broad; stem 2 to 3 inches long.

This species is edible, but slightly tough. Its characters are quite constant, and it should be recognized by the violaceous color of the cap when moist, the grayish hue when dry, and the persistent violaceous color of the gills.

Clitocybe dealbata. (Edible.)

Cap convex, then plane, finally revolute and undulate, dry, even, smooth, somewhat shining; **flesh** thin, dry, white; **gills** adnate, crowded, scarcely decurrent, white; **stem** equal, erect or ascending, stuffed, wholly fibrous, apex subpruinose.

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[1] Berkeley.

Cap 1 to $1\frac{1}{2}$ inches broad; stem about 1 inch long.

This species is edible, common, and of quite wide distribution, occurring in grass and woodlands. The ivory top is quite distinctive.

Clitocybe illudens. (Poisonous.)

Cap fleshy, convex or expanded, then depressed, sometimes with a small umbo, saffron yellow, in age becoming sordid or brownish; **gills** broad, distant, unequally decurrent; **stem** solid, firm, smooth and tapering toward the base, ascending, curved, rarely erect, color same as cap.

Cap 4 to 6 inches broad; stem 5 to 8 inches long. (Pl. X, fig. 1; from M. A. Williams.)

This is a very striking fungus both on account of its color and the large clumps it forms about stumps or decaying trees. It is often irregular in form, from the crowded habit of growth. On account of the phosphorescence which renders it conspicuous at night, it is commonly known as the jack-o'-lantern. While not considered poisonous, it produces illness and is to be carefully avoided. It may be found from August to October.

Clitocybe laccata. (Edible.)

Cap thin, convex or later expanded, even or slightly umbilicate, smooth or scurfy, hygrophanous when moist, dull reddish yellow; **gills** adnate, notched or decurrent, pinkish; **stem** slender, equal, fibrillose, purple, base clothed with a white tomentum.

Cap one-half to 2 inches broad; stem 1 to sometimes 5 inches long. (Pl. XI, fig. 2.)

In *Clitocybe laccata* the flesh is thin, of poor flavor, and inclined to be tough. It has a wide geographic range, is common, and extremely variable in form and character of habitat.

Clitocybe monadelpha. (Edible.)

Cap fleshy, convex, then depressed, at first smooth, later scaly, honey colored to pallid-brownish or reddish; **gills** short, decurrent, flesh colored; **stem** elongated, twisted, crooked, fibrous, tapering at the base, pallid brownish.

Cap 1 to 3 inches broad; stem 3 to 7 inches long. (Pl.VIII, fig. 2; from C. G. Lloyd.)

This species bears a resemblance to *Armillaria mellea*, but may be distinguished from it by the absence of a ring and the decurrent gills. The plants are edible, but soon become water soaked and uninviting. They grow in large clusters in grass or about roots or stumps and are to be found from spring until late fall.

Clitocybe multiceps. (Edible.)

Cap convex, fleshy, firm, thin except on the disk, slightly moist in wet weather, whitish, grayish, or yellowish gray, in young plants sometimes quite brown; **flesh** white, taste mild; **gills** white, close, adnate or somewhat decurrent; **stem** equal or little thickened, solid or stuffed, elastic, firm, somewhat pruinose at the apex.

Cap 1 to 3 inches broad; stem 2 to 4 inches long. (Pl. XI, fig. 1.)

This species is subject to great variation in size, color, shape of gills, texture, and taste. Sometimes the gills are very slightly sinuate, reminding one of the genus Tricholoma. *Clitocybe multiceps* appears abundantly in the spring and autumn, growing in dense clusters often hidden by the grass or stubble. It is edible and by many considered very good.

Clitocybe ochropurpurea.

Cap subhemispherical to flat, in age upturned and irregular, pale yellow or yellowish tan, slightly changing to purple, smooth or somewhat hairy; **gills** adnate or decurrent, thick, broader behind, purple; **stem** solid, equal or swollen in center, conspicuously fibrous, paler in color than the pileus.

Cap 2 to 4 inches broad; stem $2\frac{1}{2}$ to 5 inches long. (Pl. XII, fig. 2.)

This species is very common in the summer and autumn and exhibits a decided preference for clayey soil. It occurs in grassy places or open woods, either solitary or in small clusters.

Clitocybe ochropurpurea is edible and though tough is said to be excellent when well cooked.

OMPHALIA.

In the genus Omphalia the cap is generally thin, at first umbilicate, but later funnel shaped, with the margin either incurved or straight. The stem is cartilaginous, its flesh being continuous with that of the pileus but differing in character. Species of Omphalia are common on rotten wood on hilly slopes and especially abundant in damp weather. Some species are extremely small.

The genus is closely related to Mycena and Collybia, but it is separated from them by the character of the gills, which are decurrent from the first.

Omphalia campanella. (Edible.)

Cap campanulate, sometimes expanded, umbilicate, smooth, hygrophanous, rusty yellow, slightly striate; **gills** narrow, arcuate, yellow, connected by veins, decurrent; **stem** slender, horny, smooth, hollow, brown, paler at apex, hairy at base.

Cap 4 to 8 lines broad; stem may be 1 inch long and scarcely 1 line thick. (Pl. XII, fig. 1.)

This little fungus may be found during the summer and fall. It is very common and widely distributed, growing on rotten logs in clusters or tufts, and exhibits a preference for coniferous wood. It is edible, tender, and of a fairly good flavor.

TRICHOLOMA.

The genus Tricholoma is large and contains both edible and poisonous species, most of which are autumnal and terrestrial. The cap is fleshy, convex, never truly umbilicate or umbonate. A volva and ring are wanting. The gills are attached to the stem and sinuate, the degree depending upon the particular species. It has a fleshy-fibrous stem, generally short and stout, the flesh of which is continuous with that of the cap.

Tricholoma equestre. (Edible.)

Cap convex becoming expanded, margin incurved at first, then slightly wavy, viscid, sometimes scaly, pale yellowish with a greenish or brownish tinge; **flesh** white or slightly yellow; **gills** sulphur yellow, crowded, rounded behind, and almost free; **stem** stout, solid, pale yellow, or white.

Cap 2 to 3 inches broad; stem 1 to 2 inches long, one-half to three-fourths inch thick. (Pl. XIII, fig. 1; Pl. XIV, fig. 3.)

This species has a fairly wide geographical distribution and occurs very abundantly in Virginia, Maryland, and the District of Columbia from the middle of November until about Christmas. It is to be found in pine woods, where it forms irregular or incomplete fairy rings. The plants exert considerable force in pushing their way out of the ground and through the dense mat of needles, which often adhere so closely to the caps that slight elevations are the only indications of the presence of the mushrooms.

Tricholoma equestre is a very excellent edible species and is delicious when fried or made into soup. The latter resembles turkey soup, but possesses a more delicate flavor.

FIG. 1.—ARMILLARIA VENTRICOSA (YOUNG SPECIMEN).

FIG. 2.—ARMILLARIA VENTRICOSA (MATURE SPECIMEN).

FIG. 1.—CLITOCYBE ILLUDENS. (POISONOUS.)

FIG. 2.—CANTHARELLUS CIBARIUS. (EDIBLE.)

FIG. 1.—CLITOCYBE MULTICEPS. (EDIBLE.)

FIG. 2.—CLITOCYBE LACCATA. (EDIBLE.)

FIG. 1.—OMPHALIA CAMPANELLA. (EDIBLE.)

FIG. 2.—CLITOCYBE OCHROPURPUREA. (EDIBLE.)

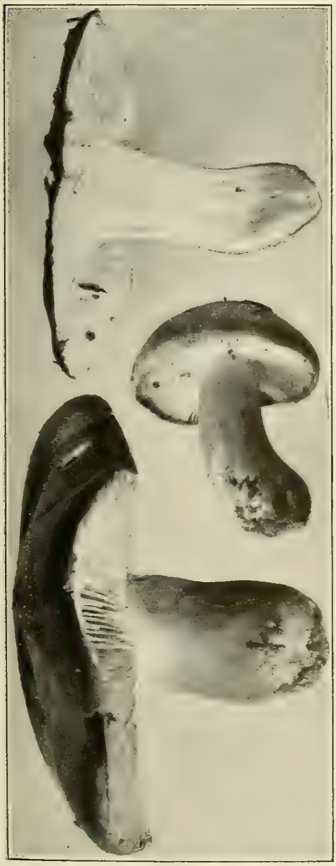

FIG. 1.—TRICHOLOMA EQUESTRE. (EDIBLE.)

FIG. 2.—URNULA CRATERIUM. (EDIBLE.)

FIG. 3.—AGARICUS CAMPESTRIS. (EDIBLE.)

FIG. 1.—TRICHOLOMA PERSONATUM. (EDIBLE.)

FIG. 2.—TRICHOLOMA TERREUM. (EDIBLE.)

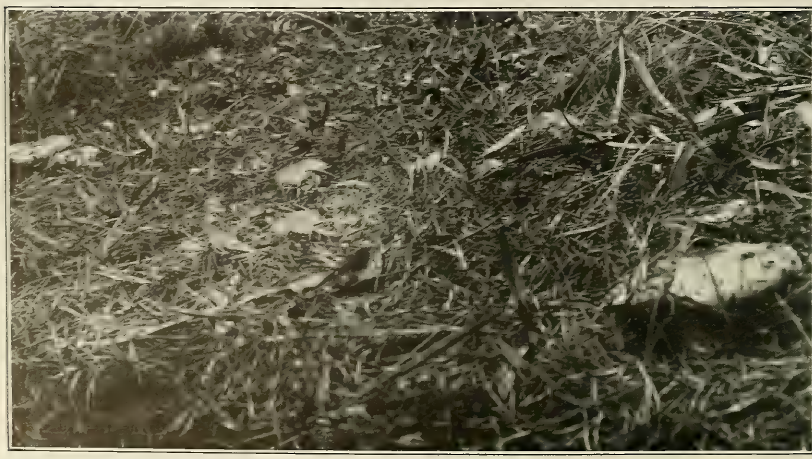

FIG. 3.—TRICHOLOMA EQUESTRE, SHOWING HABITAT. (EDIBLE.)

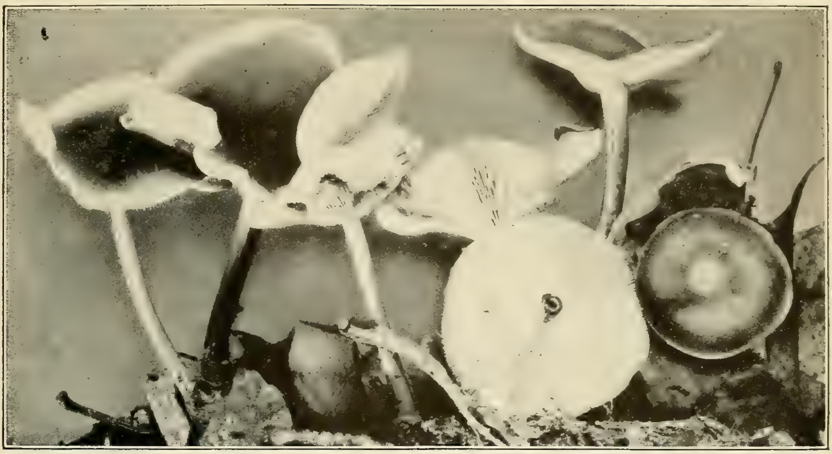

FIG. 1.—COLLYBIA BUTYRACEA. (EDIBLE.)

FIG. 2.—COLLYBIA DRYOPHILA. (EDIBLE.)

FIG. 3.—COLLYBIA VELUTIPES. (EDIBLE.)

FIG. 1.—COLLYBIA PLATYPHYLLA, TWO PLANTS AND SECTION OF CAP SHOWING BROAD GILLS. (EDIBLE.)

FIG. 2.—COLLYBIA PLATYPHYLLA, SHOWING HABITAT. (EDIBLE.)

Tricholoma nudum. (Edible.)

Entire plant at first violaceous, becoming paler and sometimes reddish; **cap** convex, then expanded and sometimes depressed, moist, smooth, margin incurved, thin, naked, flesh colored, comparatively thin, but firm and solid; **gills** crowded, rounded behind, and somewhat decurrent if cap is depressed, violet, but later may be reddish; **stem** equal, stuffed, violaceous, becoming pale.

Cap 2 to 3 inches broad; stem 2 to 3 inches long, one-half inch thick.

Edible, very good; according to all authorities, the more delicate flavor of young plants makes them preferable to those in which the color changes have taken place; on rich ground among leaves.

Tricholoma personatum. (Edible.)

Cap convex, expanded, slightly depressed, fleshy, moist, pale tan, tinged gray or violet, young plants may be entirely violet, margin downy, involute; **flesh** whitish; **gills** crowded, rather broad, rounded behind, nearly free, violaceous, changing to dull reddish brown; **stem** stout, subbulbous, fibrillose, solid, colored like cap or lighter.

Cap 2 to 5 inches broad; stem $1\frac{1}{2}$ to $2\frac{1}{2}$ inches long, one-half to three-fourths inch thick. (Pl. XIV, fig. 1.)

Tricholoma personatum is to be found quite commonly in the late summer and fall months on the ground in the woods and open places. One of the most acceptable edible species.

Tricholoma personatum and *T. nudum* are often confusing to the amateur, but may be separated from each other by the fact that in *T. nudum* the margin of the cap is naked and thinner than in *T. personatum.*

Tricholoma russula. (Edible.)

Cap convex, later plane, and sometimes depressed in center, granular, viscid in damp weather, red or flesh colored, becoming lighter at the margin, which is involute and in young plants downy; **flesh** white or tinged with red under the cuticle, taste mild; **gills** rounded or somewhat decurrent, rather distant, white, later becoming red spotted; **stem** solid, white, stained with red dots, or squamules.

Cap 3 to 5 inches broad; stem 1 to 3 inches long, one-half to three-fourths inch thick.

This species is to be found in mixed woods and hilly slopes from August until after frost. It may occur solitary, but often is found in patches. Edible and reported of fine flavor.

There is frequently a sharp line of demarcation which appears like a well-defined ridge between the gills and the substance of the stem.

Tricholoma terreum. (Edible.)

Cap fleshy, convex, or nearly plane, sometimes umbonate, innately fibrillose, floccose or scaly, grayish brown or mouse colored; **flesh** white or light gray; **gills** subdistant, adnexed, white or ash colored; **stem** solid or hollow.

Cap 1 to 3 inches broad; stem 1 to 2 inches long. (Pl. XIV, fig. 2.)

This species grows on the ground in mixed or coniferous woods. It is found abundantly from September to November and much later in Virginia, Maryland, and the District of Columbia.

Tricholoma terreum frequently occurs in association with *T. equestre*, appearing in abundance when the season has been too dry for a good run of *T. equestre*.

COLLYBIA.

In the genus Collybia the volva and veil are both wanting, and the cap is fleshy, usually thin with incurved margin. The gills are free, notched or sinuate, membranaceous, and soft; the stem is cartilagi-

nous or hollow, with a cartilaginous bark, and differs in substance from the cap.

Mycena and Collybia both have cartilaginous stems, but in young plants of Collybia the margin of the cap is inrolled, while in Mycena it is straight and closely applied to the stem.

Species of Collybia are to be found in woods on rotten stumps, on decayed leaves, and on lawns. A strong alkaline or rancid odor is peculiar to some species, and the presence of such a character should be noted while collections are fresh. Many species are edible.

Collybia butyracea.

Cap reddish brown, dark in center, becoming pale toward the margin, convex, then expanded, somewhat umbonate, smooth, even, dry but feeling oily; **flesh** soft, buttery, white or flesh colored; **gills** thin, crowded, slightly adnexed, edge notched, white, never spotted; **stem** cartilaginous, striate, hollow or stuffed, reddish, generally smooth, but may be downy, attenuated upward.

Cap 2 to 3 inches broad; stem 2 to 3 inches long. (Pl. XV, fig. 1; from Geological and Natural History Survey of Connecticut.)

Collybia butyracea may be distinguished from *C. dryophila*, by the variable color of the dark, umbonate, greasy-looking cap, the somewhat uneven edges of the gills, and the upward-tapering stem. It is found solitary or gregarious in woods, especially under coniferous trees, and it is reported to be edible.

Collybia dryophila.

Cap convexo-plane, sometimes depressed in center, smooth, tan or reddish bay brown, margin even or sometimes irregular, incurved when young; **flesh** white, thin; **gills** narrow, crowded, almost free, or with a decurrent tooth, white or pale; **stem** smooth, cartilaginous, hollow, yellowish or reddish, base sometimes enlarged.

Cap 1 to 3 inches broad; stem 1 to 3 inches long, 2 to 4 lines thick. (Pl. XV, fig. 2.)

The species is common, usually found in woods, but sometimes in lawns and open places, and is subject to variations difficult to definitely describe. One peculiarity occasionally observed is the development of certain abnormal outgrowths of the cap tissue.

Collybia dryophila is reported to be edible by American mycophagists, but one foreign authority has cited a case of illness which followed its use.

Collybia platyphylla. Broad-gilled Collybia. (Edible.)

Cap convex, then expanded plane, brown or grayish, streaked with dark fibrils, watery when moist, margin upturned in wet weather or when old; **flesh** white; **gills** broad, distant, deeply emarginate, white, soft, broken or cracked when old; **stem** whitish, stuffed, striate, sometimes powdered at the apex, bluntly rooted.

Cap 3 to 4 inches broad; stem 3 to 4 inches long, 6 lines thick. (Pl. XVI, figs. 1 and 2.)

This quite common species is one of the large mushrooms found in the early spring and continuously until autumn. In common with several species of this genus, it presents numerous variations and abortive growths; hence, its identification is sometimes puzzling. The abundant, cordlike rooting mycelium may assist in its recognition. It grows either solitary or gregarious on ground containing decaying wood and among leaves near old stumps.

Collybia radicata. Rooting Collybia. (Edible.)

Cap convex to nearly plane, distinctly umbonate, often wrinkled, especially near the umbo, grayish brown or almost white, glutinous when moist, margin incurved when young, sometimes upturned when mature; **flesh** thin, white; **gills** white, broad, ventricose, distant, adnexed, sometimes notched behind; **stem** smooth, striate, grooved or mealy, straight, slightly twisted, same color as the cap, but generally paler, slightly tapering upward, and with a long, rooting base.

Cap $1\frac{1}{2}$ to 3 inches broad; stem 4 to 8 inches long, 3 to 5 lines thick. (Pl. II, fig. 3.)

The "rooted Collybia" may be found in woods or on shaded grassy places, either singly or in groups. It is readily recognized by the distinctive character of the gills and by the tapering, pointed root, which often greatly exceeds the stem in length. It has always been reported as edible and possessing a sweet, delicate flavor until recently, when collections of distinctly bitter plants were made in New York.

Collybia velutipes. (Edible.)

Cap convex, soon plane, sometimes irregular and excentric, smooth, viscid, tawny yellow, with margin probably lighter than the disk; **flesh** thick in the center, thin at the margin, soft, watery, white or yellowish; **gills** broad, rather distant, unequal, tawny or light yellow, rounded behind and slightly adnexed; **stem** tough, cartilaginous, densely velvety villose, deep umber becoming black, equal or slightly enlarged at base, hollow or stuffed.

Cap 1 to 3 inches broad; stem 1 to 3 inches long, 2 to 4 lines thick. (Pl. XV, fig. 3; from C. G. Lloyd.)

The velvety-stemmed Collybia is readily recognized by its dark villose stem and viscid cap, which in wet weather may even appear to have a thick, glutinous coat. It grows on ground which contains decaying wood, on stumps, or even on living trees where the mycelium may have gained entrance through a wound. In such instances it assumes a semiparasitic habit and considerable injury to the tree may result. While *Collybia velutipes* is reported as occurring in every month of the year, it is especially a cold-weather species.

MYCENA.

In the genus Mycena the cap is thin, conic or bell shaped, and usually streaked with longitudinal lines. In some species it is blunt or umbonate when expanded. The margin is at first straight and closely applied to the stem. The gills are adnate or adnexed, and in some species there is a slight decurrent tooth.

The plants are small, brittle, and often possess a strong alkaline odor or an odor of radishes, which frequently disappears in drying. As the odor is not permanent, the collector should promptly note the character when the specimens are fresh. One species not here described is bitter.

Mycena epipterygia.

Cap conic or bell shaped, rather obtuse, gray, viscid, skin peeling off readily when moist, margin striate, sometimes notched; **gills** whitish or gray, tinged with red or blue, decurrent by a tooth; **stem** tough, hollow, flexuous or straight, yellowish or same color as cap, viscid when moist, villose at base.

Cap one-half to 1 inch broad; stem 2 to 4 inches long, perhaps less than 1 line thick.

These little plants are widely distributed and grow either solitary or in clusters on the ground or on branches among moss and dead leaves. They are devoid of the alkaline odor possessed by a number of the other species of this genus. The subject of their edibility appears not to have received attention.

Mycena galericulata. (Edible.)

Cap conical, bell shaped, umbonate when expanded, dry and smooth, brownish gray, striate to the umbo; **gills** white to flesh colored, adnate, slightly decurrent, rather distant, unequal, connected by veins; **stem** hollow, rigid, polished, villose at base.

Cap three-fourths inch to 1½ inches broad; stem 1 to 3 inches long, 2 lines thick. (Pl. XVII, fig. 1; from F. E. Clements.)

This is an extremely variable species. Authors sometimes recognize three varieties, *longipes*, *expansus*, and *calopus*. The variety *longipes* is distinguished by the extreme length of the stem, the variety *expansus* by the breadth and expansion of its cap, and *calopus*, the most attractive variety, by the chestnut-colored stem. The plants are common and often abundant, generally growing in clusters united by the downy hairs of the base of the stems. Both caps and stems of young plants are reported edible and as possessing a delicate flavor.

Mycena polygramma.

Cap conical, bell shaped, umbonate when expanded, smooth, grayish brown, margin striate; **gills** narrow, white, adnate, and slightly decurrent; **stem** tough, hollow, shining, striate or sulcate, paler than the cap, villose at base.

Cap three-fourths to 1 inch broad; stem about 5 inches long and 1 line thick.

This species closely resembles *Mycena galericulata* and has the same general habit of growth, the main point of difference being its long, tough, shining striate or parallel-grooved stem.

Mycena pura.

Cap conical, bell shaped, or convex and expanded, obtusely umbonate, smooth or sometimes rugose in the center, rose colored, purple, or lilac, margin finely striate; **gills** broad, adnate to sinuate when old, entirely white or colored like the cap and white on the edge, which is sometimes wavy; **stem** white when young, later colored like the cap and lighter at apex, straight or ascending, hollow, smooth or slightly villose at base.

Cap three-fourths inch to 1½ inches broad; stem 2 to 3 inches long, 1 to 2 lines thick.

This species is common, widely distributed, and may be collected in moist woods or open grassy places. The entire plants are of an almost uniform color and have a strong odor of radishes.

LACTARIUS.

The distinguishing feature of the genus Lactarius is the presence of a white or colored milk, especially in the gills. The entire plant is brittle and inclined to rigidity. The fleshy cap is more or less depressed and frequently marked with concentric zones. The gills are often somewhat decurrent, but in certain species are adnate or adnexed, unequal in length, and often forked. The stem is stout, rigid, central, or slightly excentric.

Lactarius chelidonium. (Edible.)

Cap firm, convex and depressed in the center, glabrous, slightly viscid when moist, grayish yellow or tawny, at length stained bluish or greenish, generally zonate, margin involute at first and naked; **gills** narrow, crowded, sometimes forked, and sometimes joining to form reticulations, adnate or slightly decurrent, saffron yellow to salmon; **stem** short, nearly equal, hollow, colored like the cap.

Cap 2 to 2½ inches broad; stem 1 to 1½ inches long, about one-half inch thick. (Pl. XVII, fig. 2.)

This species is closely related to *Lactarius deliciosus*, to which in flavor and substance it is scarcely inferior. It is paler than that species and the milk is saffron yellow rather than orange. The plants are fragile and when wounded turn blue, and later green. They are to be found especially in dry localities in the vicinity of pine woods in September and October.

Lactarius deceptivus. (Edible.)

Cap fleshy, convex umbilicate, then expanded and centrally depressed, somewhat infundibuliform, white or whitish, margin at first involute, covered with a dense soft cottony tomentum, filling the space between the margin and the stem, finally spreading or elevated and more or less fibrillose; **gills** whitish or cream colored, rather broad, distant or subdistant, adnate or decurrent, forking; **stem** solid, nearly equal, pruinose-pubescent.

Cap 2½ to 5½ inches broad; stem three-fourths inch to 3 inches long. (Pl. XVII, fig. 3.)

Lactarius deceptivus is found in woods and open places from July to September. It is coarse, but fairly good after its peppery taste is lost by cooking.

Lactarius deliciosus. (Edible.)

Cap convex, but depressed in the center when quite young, finally funnel shaped, smooth, slightly viscid, deep orange, yellowish or grayish orange, generally zoned, margin naked, at first involute, unfolding as the plant becomes infundibuliform; **flesh** soft, pallid; **gills** crowded, narrow, often branched, yellowish orange; **stem** equal or attenuated at the base, stuffed, then hollow, of the same color as the cap except that it is paler and sometimes has dark spots.

Cap 2 to 5 inches broad; stem 1 to 2 inches long, 1 inch thick.

This fungus is distinctive, on account of its orange color and the concentric zones of light and dark orange on the cap and because of the saffron red or orange milk. A peculiarity of the plant is that it turns green upon bruising and in age changes from the original color to greenish. *Lactarius deliciosus* is widely distributed and of common occurrence, appearing on the ground in woods, solitary or in patches, from June or July to October. As the name indicates, it is considered a delicious species, and that it has a preeminent claim to the name is unchallenged. Even by the ancients it was considered "food for the gods."

Lactarius fumosus. (Suspicious.)

Cap convex, plane or slightly depressed, snuff brown or coffee colored, dry glabrous or pruinose, very smooth, margin entire or sometimes wavy; **flesh** white, changing to reddish when wounded; **gills** subdistant, adnate, or slightly decurrent, white then yellow, becoming pinkish or salmon where bruised; **stem** nearly equal or slightly tapering downward, stuffed, then hollow, colored like the cap.

Cap 2 to 3 inches broad; stem 1½ to 2½ inches long, about 6 lines thick.

This species varies considerably in size, color, and closeness of the gills. The distinguishing features for field identification are the coffee-colored cap and the changeable color of the flesh and gills. Its use should be strictly avoided, as it closely resembles *Lactarius fuliginosus*, a poisonous species. These two species, *L. fumosus* and *L. fuliginosus*, are sometimes considered identical.[1]

Lactarius indigo. (Edible.)

Cap at first umbilicate and the margin involute, later cap depressed or infundibuliform and margin elevated, indigo blue with a silvery gray luster, zonate, fading in age, becoming greenish and less distinctly zoned, milk abundant and dark blue; **gills** crowded, indigo blue, changing to greenish in age; **stem** short, nearly equal, hollow.

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[1] Burlingham, Gertrude S. Study of the Lactariæ of the United States. Memoirs, Torrey Botanical Club, v. 14, no. 1, p. 84, 1908.

Cap 2 to 5 inches broad; stem 1 to 2 inches long. (Pl. XVIII, fig. 2.)

Lactarius indigo is easily recognized by its striking blue color. It occurs in mixed or coniferous woods in summer and autumn. Though not particularly abundant, several plants are generally found in fairly close range of one another.

Lactarius piperatus. Pepper cap. (Edible.)

Cap fleshy, thick, convex, umbilicate, when mature funnel shaped, even, smooth, zoneless, margin involute when young; **flesh** white; **gills** narrow, crowded, edge obtuse, in some forms arcuate, and then extended upward, white, reported with occasional yellow spots; **stem** equal or tapering below, thick, white, sometimes pruinose.

Cap 3½ to 5 inches broad, sometimes reported considerably larger; stem 1 to 2 inches long. (Pl. XVIII, fig. 1; from G. F. Atkinson.)

The milk in the "pepper cap" is abundant, white, unchangeable, and extremely acrid, to which character is due the specific name. This species is very common and abundant from June to October.

Lactarius torminosus. (Poisonous.)

Cap convex then depressed, surface viscid when young or moist, yellowish red or ochraceous with pink shades, margin involute when young, persistently tomentose hairy; **gills** crowded, narrow, often tinged with yellow or flesh color; **stem** cylindrical or slightly tapering at the base, hollow, whitish.

Cap 2 to 3½ inches broad; stem 1½ to 3 inches long, 4 to 8 lines thick. (Pl. XVIII, fig. 3; from G. F. Atkinson.)

According to some authors this species is injurious only when raw. It is cooked and eaten in Sweden. In Russia it is enjoyed dressed with oil and vinegar or it is preserved by drying.

Lactarius volemus. (Edible.)

Cap convex, nearly plane or slightly depressed, glabrous, dry, azonate, brownish terra cotta, somewhat wrinkled when old; **gills** adnate or slightly decurrent, close, whitish, becoming sordid or brownish when bruised; **stem** more or less equal, firm, solid, glabrous, colored like the cap or paler; milk white, abundant, and mild, becoming thick when exposed to the air.

Cap 2 to 5 inches broad; stem 1 to 4 inches long, 4 to 10 lines thick. (Pl. XIX, fig. 1.)

This species is considered delicious, and is quite common from midsummer to frost on semicleared or sprout land.

RUSSULA.

The genus Russula is similar in form, brittleness, and general appearance to Lactarius, from which it differs only in the absence of milk. The species are very abundant in the summer, extending into the fall months.

Most species of Russula are regarded as edible, but several are known to be poisonous. It is advisable to abstain from eating any red forms until perfectly familiar with the different species.

Russula emetica. (Poisonous.)

Cap oval to bell shaped, becoming flattened or depressed, smooth, shining, rosy to dark red when old, fading to tawny, sometimes becoming yellow, margin finally furrowed and tuberculate; **flesh** white, but reddish under the separable pellicle; **gills** nearly free, somewhat distant, shining white; taste very acrid; **stem** stout, spongy-stuffed, fragile when old, white or reddish.

Cap 3 to 4 inches broad; stem 2½ to 4 inches long.

Russula emetica is a handsome plant of wide distribution found during summer and autumn on the ground in woods or open places. Although some enthusiastic mycophagists testify to its edibility, it is best to consider the species poisonous.

Russula ochrophylla.

Cap convex, becoming nearly plane or very slightly depressed in the center, when old purple or purplish red, margin even, sometimes faintly striate when old; **flesh** white, purplish under the cuticle; **gills** adnate, entire, a few forked at the base, interspaces somewhat venose, at first yellowish, ochraceous buff when mature, powdery from the spores; **stem** mostly equal, solid or spongy within, rosy or red, paler than the cap.

Cap 2 to 4 inches broad; stem 2½ to 3 inches long.

Russula ochrophylla may be found growing singly or in small patches on the ground in woods, mostly under trees, according to Prof. Peck, especially under oak trees. In Virginia, Maryland, and the District of Columbia it is abundant in July and August and is to be found less frequently in September and the first part of October.

Russula roseipes. (Edible.)

Cap convex, sometimes plane or slightly depressed, at first viscid, then dry and faintly striate on the margin, rosy red, frequently modified by pink or ochraceous shades; **gills** moderately close, ventricose, more or less adnate, whitish becoming yellow; **stem** stout, stuffed or somewhat hollow, white tinged with red.

Cap 1 to 2 inches broad; stem 1½ to 3 inches long.

This species grows on the ground in mixed, but generally coniferous, woods. It appears in the late summer and autumn and is reported excellent, though, as already stated, the amateur should be cautious and avoid all red species of this genus.

Russula rubra.

Cap convex, flattened, finally depressed, dry, pellicle absent, polished, cinnabar red, becoming tan when old; **flesh** white, reddish under the cuticle; **gills** adnate, somewhat crowded, whitish then yellowish, often red on the edge; **stem** stout, solid, varying white or red.

Cap 2½ to 4 inches broad; stem 2 to 3 inches long, about 1 inch thick.

This species is extremely acrid, and, as there are conflicting opinions concerning its edibility, it is best for the amateur to refrain from collecting it. It is found in woods on the ground in summer and autumn.

Russula virescens. (Edible.)

Cap at first rounded, then expanded, when old somewhat depressed in the center, dry, green, the surface broken up into quite regular, more or less angular areas of deeper color, margin straight, obtuse, even; **gills** adnate, somewhat crowded, equal or forked; **stem** equal, thick, solid or spongy, rivulose, white.

Cap 3½ to 5 inches broad; stem about 2 inches long. (Pl. XIX, fig. 2.)

This fungus is noticeable on account of the color and areolate character of the cap. In Virginia, Maryland, and the District of Columbia it occurs commonly either solitary or in small patches, but not in very great abundance, from July to September, but it has been found from June through the entire summer and into October. The species is edible and of good flavor.

HYGROPHORUS.

In the genus Hygrophorus the cap is viscid, moist, or hygrophanous, and the flesh is continuous with that of the stem. The gills are generally distant, adnexed, adnate or decurrent, thick with acute edge, watery, and of waxy consistency. Hygrophorus is closely related to Cantharellus, the gills of which are blunt and forked but never waxy.

In Hygrophorus the cap is sometimes regular but often plicate or folded and the margin irregular, wavy, or lobed. The genus is comprised of many attractive species, some of which are conspicuous because of their bright colors.

Hygrophorus chrysodon. (Edible.)

Cap fleshy, convex, then expanded, margin involute when young, viscid, shining when dry, white, with scattered golden squamules; **gills** white, distant, decurrent; **stem** stuffed, soft, nearly equal, white, with minute yellow squamules, more numerous toward the apex, where they are often arranged in the form of a ring.

Cap 2 to 3 inches broad; stem 2 to 3 inches long.

This plant is easily recognized on account of the golden granules on the cap and stem. It grows on the ground in woods or open situations in the late summer and fall, but is not of very common occurrence.

Hygrophorus coccineus. (Edible.)

Cap convexo-plane, obtuse, hygrophanous, smooth, scarlet, becoming yellowish in age, fragile, generally unequal; **gills** adnate, decurrent with a tooth, distant, connected by veins, light yellow in the middle, purplish at the base when mature; **stem** hollow then compressed, base always yellow, scarlet upward.

Cap 1 to 2 inches broad; stem about 2 inches long.

This species occurs in moist places and on mossy banks.

Hygrophorus conicus. (Edible.)

Cap strikingly conical, yellow, orange, scarlet, margin often lobed; **gills** free or adnate, rather loose and broad, yellow; **stem** equal, hollow, fibrous striate, yellow or scarlet.

Cap one-half to 1 inch broad; stem 3 to 5 inches long.

This is a very attractive little fungus on account of its bright color and symmetrical conical cap. A very distinctive character is the blackening of the fungus in drying. It occurs on the ground in rich woods and in damp places near streams from August to September or later.

Hygrophorus eburneus. (Edible.)

Cap fleshy, sometimes thin, again moderately thick, convex to expanded, smooth, white, exceedingly glutinous, margin involute when young, later wavy; **gills** decurrent, distant, veined at the base; **stem** unequal, spongy to stuffed, sometimes hollow, glutinous, attenuated toward the base.

Cap 1 to 3 inches broad; stem quite variable in length.

This species possesses a fair flavor and mild odor, but is of rather tough consistency. It occurs in woods and pastures in the fall, September to October.

Hygrophorus hypothejus. (Edible.)

Cap convex, somewhat depressed, at first covered with an olivaceous slime, after its disappearance ash colored, pale yellow, orange, or often rufescent; **flesh** thin, white, becoming light yellow; **gills** decurrent, distant, whitish or pallid, later yellow or flesh colored; **stem** equal, viscid, stuffed, becoming hollow, paler than the cap.

Cap 1 to $1\frac{1}{2}$ inches broad; stem 2 or more inches long.

This is an interesting little species, occurring late in the fall in pine woods. The partial veil is floccose, but early fugacious, and is of such a transitory character that it is of very little value to the amateur in identifying the species. It is edible, though not especially adapted to cooking, but when dried it is nutty and fairly palatable.

FIG. 1.—MYCENA GALERICULATA. (EDIBLE.)

FIG. 2.—LACTARIUS CHELIDONIUM. (EDIBLE.)

FIG. 3.—LACTARIUS DECEPTIVUS. (EDIBLE.)

FIG. 1.—LACTARIUS PIPERATUS.

FIG. 2.—LACTARIUS INDIGO. (EDIBLE.)

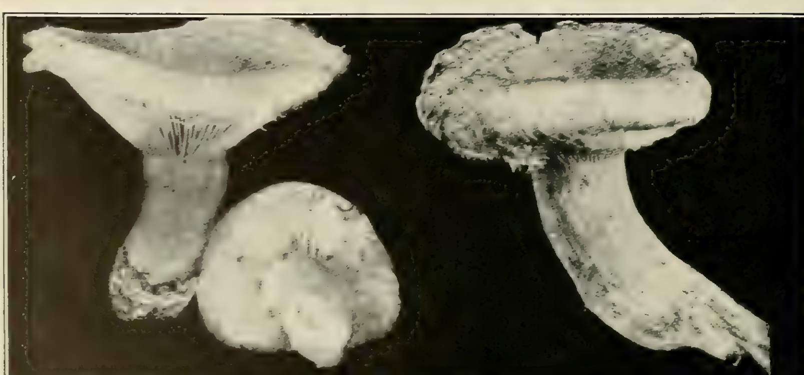

FIG. 3.—LACTARIUS TORMINOSUS. (POISONOUS.)

FIG. 1.—LACTARIUS VOLEMUS.

FIG. 2.—RUSSULA VIRESCENS. (EDIBLE.)

FIG. 3.—MARASMIUS OREADES. (EDIBLE.)

FIG. 1.—LENTINUS LEPIDEUS.

FIG. 2.—CLAUDOPUS NIDULANS.

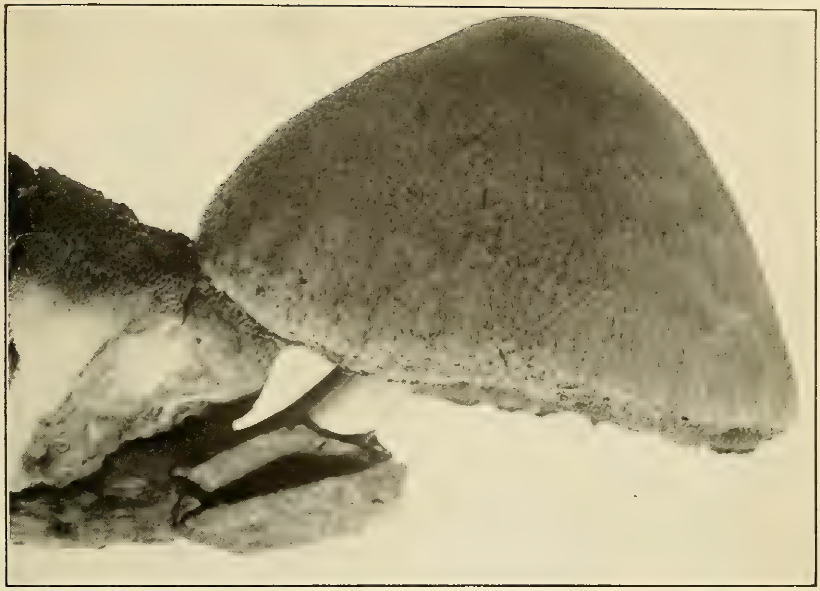

FIG. 1.—VOLVARIA BOMBYCINA.

FIG. 2.—PAXILLUS RHODOXANTHUS. (EDIBLE.)

FIG. 1.—PLUTEUS CERVINUS. (EDIBLE.)

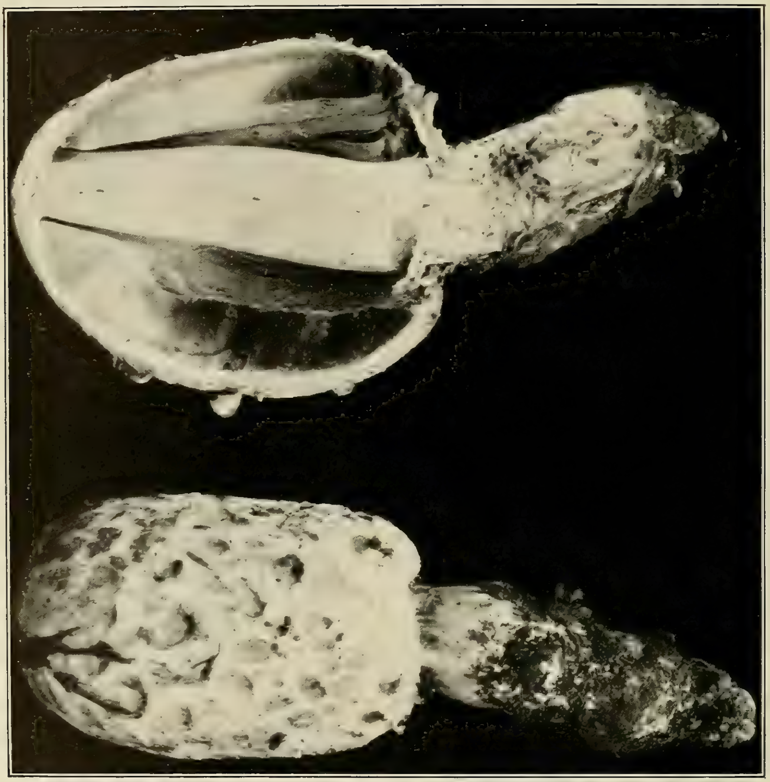

FIG. 2.—COPRINUS COMATUS. (EDIBLE.)

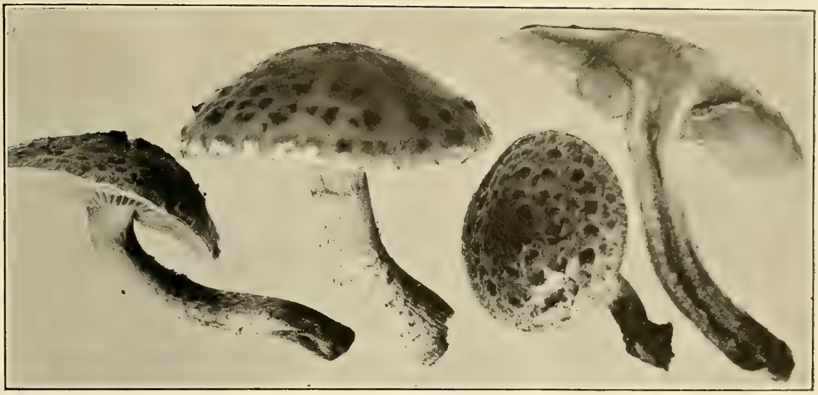

FIG. 1.—PHOLIOTA ADIPOSA. (EDIBLE.)

FIG. 2.—PHOLIOTA ADIPOSA, GROWING FROM A WOUND IN A LIVING TREE (EDIBLE.)

FIG. 1.—CORTINARIUS LILICINUS. (EDIBLE.)

FIG. 2.—PHOLIOTA SQUARROSA. (EDIBLE.)

MARASMIUS.

The plants of the genus Marasmius are thin, tough, and membranaceous, never decaying, but drying up and shriveling. When moistened they again expand and assume their original form, a character peculiar to this genus. The gills are variously attached and often narrow, distant, and connected by prominent anastomosing veins. The stem is cartilaginous or horny and continuous with the cap, but of a different texture.

Most of the species grow upon wood or leaves and some have an odor of garlic or onions. Marasmius is closely related to Collybia, Lentinus, and Panus. Certain species have been described as belonging to Collybia and are especially difficult of identification. The majority of the species of Marasmius have a central stem, while the stem in Lentinus and Panus is variable, being central, excentric, lateral, or absent. Marasmius species are also much smaller than those of the genera mentioned.

Marasmius cohaerens.

Cap fleshy, convex to plane, sometimes umbonate, tan to chestnut, perhaps darker in the center; margin wavy, striate when damp; **gills** narrow, crowded, adnate, but notched, tan colored; **stem** hollow, shining, color same as cap, darker and slightly enlarged toward the base, rooting.

Cap one-half to 1 inch broad; stem 2 to 4 inches long, 1½ lines thick.

The species grows on the ground or on rotten logs in dense clusters, as many as 20 being closely bound together by a growth of hairs at the base of the stems. It is not common but is widely distributed. It has been identified by some collectors as a member of the genus Mycena, by others as a Collybia.

Marasmius oreades. Fairy-ring fungus. (Edible.)

Cap convex, then plane and slightly umbonate, tough, smooth, brownish buff, later cream colored, margin when moist may be striate; **gills** broad, free, distant, unequal, creamy white; **stem** tough, solid, equal, villose in the upper part, smooth at the base.

Cap 1 to 2 inches broad; stem 2 to 3 inches long, 1½ lines thick. (Pl. XIX, fig. 3.)

This is a popular edible species and once learned should always be recognized. It may be preserved for winter use by drying and is also well adapted for pickling.

Marasmius rotula. The collared mushroom.

Cap white or pale yellowish and darker at the disk, papery, deeply furrowed, smooth umbilicate; margin crenate; **gills** the color of the cap, broad, distant, attached to a collar which surrounds the stem; **stem** threadlike, smooth, shining, hollow, blackish.

Cap one-fourth to one-half inch broad; stem 1 to 1½ inches long.

Commonly found on leaves and twigs in forests. The species can be at once recognized by the gills being attached to a collar free from the stem.

LENTINUS.

In the genus Lentinus the plants are tough, leathery, corky, becoming hard and almost woody when old. The cap is generally irregular in form, usually depressed, often scaly or velvety. The gills are slightly or deeply decurrent, unequal, thin with margin notched or

serrate. Some species are sessile; in others a stem is present which is central, excentric, or lateral.

The serrate gills are a constant generic character and serve to separate Lentinus from Panus, which has entire gills. Common on dead or rotten wood.

Lentinus lecomtei. Hairy Lentinus. (Edible.)

Cap variable, funnel shaped, regular or irregular, tawny or reddish brown, hairy or strigose, margin incurved; **gills** pallid, narrow, crowded, edges scarcely at all serrate; **stem** central, excentric, or lateral, generally tawny and hairy when young, sometimes becoming smooth with age.

Cap 2 to 4 inches broad; stem usually 1 to 1½ inches long.

Authorities differ as to the classification of *Lentinus lecomtei*. According to some it more properly belongs to the genus Panus. It is widely distributed and grows upon wood. The plants when young are edible and have a fine flavor.

Lentinus lepideus. Scaly Lentinus. (Edible.)

Cap convex, becoming more or less depressed and irregular, tan to yellow, with dark scales; **gills** decurrent, broad, crowded, sinuate, white; **stem** central or excentric, whitish, hairy or scaly, solid, equal, or tapering at the base.

Cap 2 to 4 inches broad, often larger, stem about 1 inch long. (Pl. XX, fig. 1; from F. E. Clements.)

This is a widely distributed species and very common, especially upon pine, oak, and decaying stumps. When young and tender it is edible, and even when old is recommended for use in soup.

PANUS.

Plants of the genus Panus closely resemble those of Lentinus, from which they differ in the character of the edge of the gills. In Panus the gills are normally entire, while in Lentinus the gills are serrate. The only difficulty in using this character as a means of generic separation is the fact that in drying out the margin of the gills may be torn or ruptured. Some authors have considered these genera identical.

Panus stipticus. Bitter Panus.

Cap pale cinnamon to grayish, kidney shaped, scurfy, tough; **gills** not decurrent, thin, narrow, crowded, connected by veins; **stem** short, lateral, solid, ascending pruinose.

Cap one-half to 1 inch broad.

This little species is common on stumps, shriveling in dry and expanding in wet weather. It is characterized by a pronounced astringent taste, which is very unpleasant in its effect on the mouth and throat, and is considered poisonous.

CLAUDOPUS.

The genus Claudopus is easily recognized among the rosy-spored agarics by the cap being excentric, lateral, or resupinate. The stem may be rudimentary or obsolete and the gills sinuate or decurrent. The plants grow upon wood in an inverted position and thus the gills are directed upward. Claudopus resembles Pleurotus and Crepidotus in habit, but differs in the color of the spores.

Claudopus nidulans.

Cap suborbicular or kidney shaped, sessile or narrowed behind into a stemlike base, caps often overlapping, yellow or buff, downy, hairy or scaly toward the involute margin; **gills** broad, rather close, orange yellow.

Cap 1 to 3 inches broad. (Pl. XX, fig. 2; source of photograph unknown.)

Claudopus nidulans is widely distributed and is to be found in the fall, growing on decaying branches, wood, etc. It is easily recognized from its shelving and sometimes resupinate habit, yellow or buff cap, and orange yellow gills. It is edible. The taste is said to be mild and pleasant, but the substance tough.

VOLVARIA.

The genus Volvaria is distinguished by the universal veil, which, becoming ruptured, remains as a large loose cup at the base of the stem, and by the absence of a ring. The stem is easily separable from the cap and the gills are usually free, rounded behind, at first white, but later pink.

The genus is comparable to Amanitopsis among the white-spored agarics in having a volva but no ring. Species of Volvaria grow in rich woods, on leaf mold or rotten wood, and on richly manured ground.

Volvaria bombycina.

Cap globose, bell shaped, later convex and sometimes subumbonate, white, silky when young, smooth at the apex, sometimes scaly when old; **flesh** white; **gills** ventricose, free, not reaching the margin, edge sometimes toothed; **stem** white, solid, smooth, tapering from base to apex; **volva** large, membranaceous, tough, somewhat viscid.

Cap 3 to 8 inches broad; stem 3 to 6 inches long, 6 lines thick. (Pl. XXI, fig. 1.)

This species is widely distributed, but nowhere common. It is found on fallen or living trees of various species.

PLUTEUS.

The genus Pluteus may be recognized among the rosy-spored agarics by its symmetrical cap, central stem distinct from the cap, and free salmon-colored gills. In addition to these features, the absence of a volva and ring will assist in the determination of the species of this genus.

These plants are usually found growing upon wood.

Pluteus cervinus. (Edible.)

Cap at first bell shaped, later convex and expanded to almost plane, fleshy, generally smooth but with radiating fibrils, or sometimes more or less scaly, light brown, grayish brown, or sooty; margin entire; **flesh** white; **gills** broad, ventricose, unequal, free, white becoming flesh colored; **stem** color of cap, paler above, firm, solid, fibrillose or subglabrous, nearly equal but slightly tapering above.

Cap 2 to 5 inches broad; stem 2 to 5 inches long, 3 to 6 lines thick. (Pl. XXII, fig. 1; from C. G. Lloyd.)

Pluteus cervinus occurs intermittently from spring to early fall. It issues from the base of decaying stumps or logs and sometimes appears in great abundance on sawdust piles. It is edible, and when young is tender and of good flavor.

ENTOLOMA.

The genus Entoloma is another rosy-spored agaric in which a volva and an annulus are absent. The cap is somewhat fleshy and the margin incurved, especially when young. The gills are adnate, adnexed, or sinuate.

In form Entoloma corresponds to Tricholoma of the white-spored, Hebeloma of the ocher-spored, and Hypholoma of the brown-spored species.

The edible quality of the species of this genus is variable. Several are reported as edible, while severe poisoning has followed the use of at least four species.

Entoloma grayanum.

Cap fleshy, convex, frequently wavy or irregular, hygrophanous, dull, watery yellow when moist, smooth, shining, and nearly white when dry; **gills** flesh colored, plane, close; **stem** equal, firm, solid, white.

Plant about 3 inches high; cap 1½ to 2 inches broad.

This species grows on the ground and is sometimes gregarious.

PAXILLUS.

In the genus Paxillus the plants are symmetrical or excentric, with a persistently incurved margin. The membranaceous gills are easily separable from the cap and frequently fork and unite, producing a poroid appearance in contrast with the usual platelike gills of agarics.

Paxillus atro-tomentosus.

Cap fleshy, compact, tough, convex, becoming plane or depressed, reddish brown, dry, often tomentose, margin thin, strongly involute; **flesh** white; **gills** adnate, decurrent, forked near the base, often reticulate, sometimes forming pores; **stem** stout, solid, generally excentric, covered with thick dark-brown or black tomentum.

Cap 3 to 5 inches broad; stem 3 to 4 inches long, one-half to 1 inch thick.

This plant is to be found in pine woods, during the late summer and autumn. It is easily recognized because of the stout, black, tomentose stem and mostly irregular cap with incurved margin. Though the species may not be poisonous, its edibility has been questioned, and therefore it is wise to avoid its use.

Paxillus involutus. (Edible.)

Cap compact, fleshy, convexo-plane, depressed, viscid when moist, tawny, ochraceous, perhaps olive or reddish brown, margin downy and strongly involute; **flesh** pallid, changing to reddish brown if bruised; **gills** crowded, decurrent, arcuate when young, branched, anastomosing, forming pores behind; **stem** solid, firm, color of the cap, sometimes slightly excentric.

Cap 2 to 4 inches broad; stem 2 to 3 inches long, about one-half inch thick.

Paxillus involutus is a summer and autumnal species. It grows on the ground or on wood, often frequenting grassy or mossy, swampy places in open woods. There is a certain similarity between this plant and Cantharellus, and on account of this resemblance *Paxillus involutus* is often spoken of as the brown chanterelle; but unlike the true chanterelle its edibility is not to be highly recommended, as the flesh is dry, coarse, and rather tasteless.

Paxillus rhodoxanthus. (Edible.)

Cap convex, when expanded plane or perhaps slightly depressed, reddish yellow or brown, densely tomentose, often becoming cracked and showing the yellowish flesh; **gills** deeply decurrent, forked, and connected by anastomosing veins, some shade of yellow; **stem** with many small, dark dots, paler than the cap, deep yellow at the base.

Plant 2 to 4 inches tall; cap $1\frac{1}{4}$ to 3 inches broad. (Pl. XXI, fig. 2; from G. F. Atkinson.)

This species is also described as *Gomphidius rhodoxanthus*. Discussion of its synonymy is given by Prof. Atkinson.[1]

PHOLIOTA.

The genus Pholiota is distinguished among the ocher-spored agarics by the presence of an annulus which is membranaceous or friable in character, never cobwebby as in Cortinarius, and it may be persistent or fugacious.

The cap is more or less fleshy, yellowish, tawny, and sometimes scaly. The gills are adnate or slightly decurrent by a tooth.

Species of Pholiota can be distinguished from brown forms of Cortinarius by the cobwebby veil of the latter.

Pholiota adiposa. (Edible.)

Cap firm, fleshy, subconical, to convex, glutinous when moist, yellowish, brown in center, often torn into dark scales, margin incurved; **flesh** thick at center, spongy, yellowish; **gills** close, adnate, sometimes notched, yellowish to rust color; **stem** firm, whitish to yellow, viscid, clothed with brownish scales below the slight, floccose ring.

Cap 2 to 4 inches broad; stem 2 to 4 inches long, 4 to 6 lines thick. (Pl. XXIII.)

This species, commonly known as the "fatty Pholiota," forms large clusters in the fall, on trunks or crotches of trees or on stumps. It is a rather showy fungus, easily attracting attention because of its tufted habit of growth, yellow color, and conspicuous scales. *Pholiota adiposa* is considered edible by American authorities, and it is substantial and of fairly good flavor. The season is mostly confined to the fall months. With this particular species it is preferable to peel the cap preparatory to cooking.

Pholiota caperata. (Edible.)

Cap fleshy, yellow to yellow-brown, ovate, obtuse or plane when expanded, viscid when moist, sometimes covered with whitish tufts; **gills** adnate, crowded, narrow, may be serrate, yellowish brown; **stem** stout, solid, sometimes slightly enlarged at base, white and shining, scaly above the ring; **ring** membranaceous, broad.

Cap $2\frac{1}{2}$ to 4 inches broad; stem 3 to 5 inches long, one-half to over 1 inch thick.

This fungus appears in the fall quite abundantly in certain localities. The specific name refers to the wrinkled character of the pileus, a prominent and constant feature of the plant. It is edible, slightly acrid when raw, but fairly good when cooked.

Pholiota marginata. (Edible.)

Cap convex, then expanded, obtuse to plane, smooth, hygrophanous, slightly fleshy, tan when dry, honey colored when moist, margin striate; **gills** adnate, crowded, narrow, when mature reddish brown; **stem** hollow, equal, smooth , or slightly fibrillose; color same as the cap, whitish velvety at base; **ring** often distant from apex of stem, soon disappearing.

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[1] Atkinson, G. F. Studies of American Fungi; Mushrooms, Edible, Poisonous, etc., ed. 2, New York, 1903, p. 167.

Cap one-half to 1 inch broad; stem 1 to 2 inches long, about 2 lines thick.

This attractive little fungus appears principally in the fall, but it may occur sparingly during the summer. It grows singly or clustered on rotten stumps or logs and is edible and of excellent quality.

Pholiota squarrosa. (Edible.)

Cap yellowish brown, clothed with dark persistent scales, dry, convex, then flattened, perhaps obtusely umbonate or gibbous; **flesh** light yellow; **gills** crowded, narrow, adnate with a decurrent tooth, pale olive, then rust colored; **stem** stuffed, yellowish brown, with dense, dark recurved scales below the ring, much thinner at base than apex; **ring** near the apex, generally floccose, seldom membranaceous and entire.

Cap 2 to 5 inches broad; stem 3 to 6 inches long. (Pl. XXIV, fig. 2; from C. G. Lloyd.)

This species occurs in many localities from the last of June until frost, growing on trunks of trees and stumps. It is conspicuous because of the large clusters and prominent scales on both cap and stem. The fungus is good, raw or cooked, and by some authorities is considered excellent.

CORTINARIUS.

The genus Cortinarius is easily recognized when young among the ocher-spored agarics by the powdery gills and by the cobwebby veil, which is separable from the cuticle of the cap. In mature plants the remains of the veil may often be observed adhering to the margin of the cap and forming a silky zone on the stem. Cortinarius contains many forms which are difficult of specific determination. Many species are edible, some indifferent or unpleasant, and others positively injurious. The colors are generally conspicuous and often very beautiful. Most of the species occur in the autumn.

Cortinarius cinnamomeus. (Edible.)

Cap rather thin, conic campanulate, when expanded almost plane, but sometimes umbonate, yellow to bright cinnamon colored, with perhaps red stains, smooth, silky from innate, yellowish fibrils, sometimes concentric rows of scales near the margin; **flesh** yellowish; **gills** yellow, tawny, or red, adnate, slightly sinuate and decurrent by a tooth, crowded, thin, broad; **stem** equal, stuffed then hollow, yellowish, fibrillose.

Cap 1 to 2½ inches broad; stem 2 to 4 inches long, 3 to 4 lines thick.

This is a very common and widely distributed species, particularly abundant in mossy coniferous woods from summer until fall. The color of the gills is an extremely variable character, ranging from brown or cinnamon to blood red. A form possessing gills of the latter color is known as *Cortinarius cinnamomeus* var. *semisanguineus*. This species and variety are edible and considered extremely good.

Cortinarius lilicinus. (Edible.)

Cap firm, hemispherical, then convex, minutely silky, lilac colored; **gills** close, violaceous changing to cinnamon; **stem** solid, stout, distinctly bulbous, silky fibrillose, whitish with a lilac tinge.

Cap 2 to 3 inches broad; stem 2 to 4 inches long. (Pl. XXIV, fig. 1.)

This is a comparatively rare but very beautiful mushroom and an excellent edible species.

Cortinarius sanguineus. (Edible.)

Cap convex, then plane, or perhaps slightly umbonate or depressed, blood red, silky or squamulose; **flesh** paler reddish; **gills** crowded, entire, adnate, dark blood red; **stem** stuffed or hollow, sometimes attenuated at the base, dark as the cap and fibrillose, containing a red juice.

Cap 1 to 1½ inches broad; stem 2 to 3 inches long.

This species is much less common in its occurrence than *Cortinarius cinnamomeus*, but is distinctive because of its entire blood-red color.

Cortinarius violaceus. (Edible.)

Cap convex, when expanded almost plane, dry with hairy tufts or scales, dark violet; **flesh** somewhat violaceous; **gills** distant, rather thick and broad, rounded or deeply notched at apex of stem, narrowed at margin of cap, at first violaceous, later brownish cinnamon; **stem** fibrillose, solid, bulbous, colored like cap.

Cap 2 to 4 inches broad; stem 3 to 5 inches long. (Pl. IV, fig. 2; from M. E. Hard.)

This very attractive species is at first a uniform violet, but with age the gills assume a cinnamon hue. The plants appear in woods and open places during the summer and fall, generally solitary, but often in considerable numbers. It is esteemed as one of the best edible species.

NAUCORIA.

Considerable variation is to be observed among species of the genus Naucoria, but distinguishing generic characters are the more or less fleshy cap, at first conical or convex, with involute margin, and the cartilaginous stem, which is hollow or stuffed. The gills are free or adnate, but never decurrent.

Naucoria semiorbicularis. (Edible.)

Cap hemispherical, convex to expanded, smooth, even, slightly viscid when moist, corrugated or cracked when dry and old, tawny, rust colored; **gills** adnate, sometimes notched, crowded, pale, then rust colored; **stem** tough, slender, straight, equal, smooth, hollow, with a free fibrous tube, pale reddish brown, darker at the base.

Cap 1 to 2 inches broad; stem 3 to 4 inches long.

This is one of the most common and widely distributed species. It is among the first to appear in the spring and continues until autumn, being particularly abundant in wet weather.

It is edible, easily cooked, and said to possess an excellent flavor.

GALERA.

The plants of the genus Galera are slender and fragile. The cap is regular, thin, more or less membranaceous, conic or bell shaped, often striate, especially when moist, margin straight, never incurved, as in Naucoria. The gills are adnate or adnexed. The stem is somewhat cartilaginous, hollow, and polished.

Galera tenera. (Edible.)

Cap cone or bell shaped, rust colored when damp, ochraceous when dry, sometimes atomate, hygrophanous, membranaceous, smooth, but striate, when damp; **gills** cinnamon, broad, ascending adnate; **stem** slender, fragile, smooth, sometimes striate, mealy above, paler than cap.

Cap 5 lines to three-fourths inch broad; stem 2 to 4 inches long. (Pl. II, fig. 2; from F. E. Clements.)

This little fungus is very common in lawns or in richly manured places, where it appears early in the spring and persists until frost. It exhibits considerable variation in size and color, the latter ranging from light tan to brown and depending upon conditions of humidity. The species is small but tender and can be preserved for winter use by drying.

AGARICUS.

The genus Agaricus is characterized by brown or blackish spores with a purplish tinge and by the presence of a ring. The cap is mostly fleshy and the gills are free from the stem. The genus is closely related to Stropharia, but separated from it by the free gills and the noncontinuity of the stem and the cap. The species of Agaricus occur in pastures, meadows, woods, and manured ground. All are edible, but certain forms are of especially good flavor. Bright colors are mostly absent and white or dingy brown shades predominate.

Agaricus arvensis. Horse or field mushroom. (Edible.)

Cap convex, bell shaped, then expanded, when young floccose or mealy, later smooth, white or yellowish; **flesh** white; **gills** white to pink, at length blackish brown, free, close, may be broader toward the stem; **stem** stout, hollow or stuffed, may be slightly bulbous, smooth; **ring** rather large, thick, the upper part white, membranaceous, the lower yellowish and radially split.

Cap 3 to 5 inches broad; stem 2 to 5 inches high, 4 to 10 lines thick.

Agaricus arvensis is to be found in fields, pastures, and waste places. It is closely related to the ordinary cultivated mushroom, but differs in its larger size and double ring. It is an excellent edible species, the delicacy of flavor and texture largely depending, like other mushrooms, upon its age.

Agaricus campestris. Common or cultivated mushroom. (Edible.)

Cap rounded, convex, when expanded nearly plane, smooth, silky floccose or squamulose, white or light brown, squamules brown, margin incurved; **flesh** white, firm; **gills** white in the button stage, then pink, soon becoming purplish brown, dark brown, or nearly black, free from the stem, rounded behind, subdeliquescent; **stem** white, subequal, smooth or nearly so; **veil** sometimes remaining as fragments on the margin of cap; **ring** frail, sometimes soon disappearing.

Cap $1\frac{1}{2}$ to 4 inches broad; stem 2 to 3 inches long, 4 to 8 lines thick. (Pl. XIII, fig. 3.)

This is the most common and best known of all the edible mushrooms. It is a species of high commercial value, lending itself to very successful and profitable artificial cultivation. It is cosmopolitan in its geographical distribution, being as universally known abroad as in America. It is cultivated in caves, cellars, and in especially constructed houses; but it also occurs abundantly in the wild state, appearing in pastures, grassy places, and richly manured ground. The only danger in collecting it in the wild form is in mistaking an Amanita for an Agaricus; however, this danger may be obviated by waiting until the gills are decidedly pink before collecting the mushrooms.

Agaricus placomyces. Flat-cap mushroom. (Edible.)

Cap thin, at first broadly ovate, convex or expanded and flat in age, whitish, adorned with numerous minute, brown scales, which become crowded in the center, forming a large brown patch; **gills** close, white, then pinkish, finally blackish brown; **veil**

broad; **ring** large. In the early stages, according to Prof. Atkinson, a portion of the veil frequently encircles the stipe like a tube, while a part remains still stretched over the gills. This condition is well illustrated in Plate XXV, figure 1. **Stem** smooth, stuffed or hollow, bulbous, white or whitish, the bulb often stained with yellow.

Cap 2 to 4 inches broad; stem 3 to 5 inches long, one-fourth to one-half inch thick. (Pl. XXV, fig. 1.)

This species frequents hemlock woods, occurring from July to September.

Agaricus rodmani. (Edible.)

Cap firm, rounded, convex, then nearly plane, white, becoming subochraceous, smooth or cracked into scales on the disk, margin decurved; **flesh** white; **gills** narrow, close, white, changing to pink and blackish brown; **stem** solid, short, whitish, smooth, or perhaps mealy, squamulose above the ring; **ring** double, sometimes appearing as two collars with space between.

Cap 2 to 4 inches broad; stem 2 to 3 inches long, 6 to 10 lines thick.

Agaricus rodmani may easily be mistaken for *Agaricus campestris*, but can be distinguished by the thicker, firmer flesh, narrower gills, which are nearly white when young, and peculiar collar, which appears double. This species grows on grassy ground, often springing from crevices of unused pavements or between the curbing and the walk. It is to be found principally from May to July.

Agaricus silvicola. (Edible.)

Cap convex, expanded to almost plane, sometimes umbonate, smooth, shining, white, often tinged with yellow, sometimes with pink, especially in the center; **flesh** white or pinkish; **gills** thin, crowded, white, then pink, later dark brown, distant from stem, generally narrowed toward each end; **stem** long, bulbous, stuffed or hollow, whitish, sometimes yellowish below; **ring** membranaceous, sometimes with broad floccose patches on the under side.

Cap 3 to 6 inches broad; stem 4 to 6 inches long, 4 to 8 lines thick.

Agaricus silvicola has been known under various names, at one time being considered merely a variety of *Agaricus arvensis*. By Peck [1] it has been recognized as a distinct species, *A. abruptibulbus*. A discussion of the nomenclature of this species may be found in McIlvaine and Macadam.[2]

Agaricus subrufescens. (Edible.)

Cap at first deeply hemispherical, becoming convex or broadly expanded, silky, fibrillose, and minutely or obscurely squamulose, whitish, grayish, or dull reddish brown, usually smooth and darker on the disk; **flesh** white, unchangeable; **gills** at first white or whitish, then pinkish, finally blackish brown; **stem** rather long, often somewhat thickened or bulbous at the base, at first stuffed, then hollow, white; the annulus flocculose or floccose squamose on the lower surface. Two additional characters of assistance in identification are the mycelium, which forms slender branching rootlike strings, and the almondlike flavor of the flesh.

Cap 3 to 4 inches broad; stem $2\frac{1}{2}$ to 4 inches long. (Pl. XXVI.)

The plants often grow in large clusters of 20 to 30 or even 40 individuals. They occur in the wild state and have also been reported as a volunteer crop in especially prepared soil. Specimens collected in the vicinity of Washington, D. C., were found growing near the river on a rocky slope rich in leaf mold. *Agaricus subrufescens* is considered a very excellent edible species.

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[1] Peck, C. H. Report of the State botanist, 1904. New York State Museum, Bulletin 94, p. 36, 1905.

[2] McIlvaine, Charles, and Macadam, R. K. Toadstools, Mushrooms, Fungi, Edible and Poisonous; One Thousand American Fungi. Rev. ed., Indianapolis, [1912], p. 728.

STROPHARIA.

The genus Stropharia is easily recognized among the purple-spored agarics, and is distinguished from Agaricus by its usually adnate gills and the continuity of the flesh of the cap and stem. A ring is always present in young plants, but often absent at maturity. The edibility of species of this genus is a disputed point among mycophagists.

Stropharia semiglobata.

Cap rounded, then hemispherical, thick at center, becoming thin toward the even margin, light yellow, viscid when moist; **gills** broad, adnate, unequal, when young light brown, later purplish brown or blackish; **stem** slender, hollow, even or slightly bulbous, smooth, yellowish, but paler at apex, where striate markings from the gills may be present, viscid; **ring** viscous, incomplete, formed by the remains of the glutinous veil, which soon disappears.

Cap 1 to 1½ inches broad; stem 2 to 3 inches long, 2 to 3 lines thick. (Pl. XXV, fig. 2.)

This species is remarkable for the uniformly hemispherical cap. It occurs commonly on dung or in well-manured ground. Opinions differ regarding its edibility, and it is consequently safe to refrain from collecting the species.

HYPHOLOMA.

The spores of the genus Hypholoma are purple brown. The margin of the cap is incurved in the young condition. The veil generally adheres by fragments to the margin of the cap, rarely forming a distinct ring. The gills are attached to the stem and sometimes are emarginate. The stem is fleshy and continuous with the substance of the cap. Hypholoma shows a close relationship to Agaricus and Stropharia, differing from both in the absence of a distinct ring, and it further differs from Agaricus, in which genus the stem and cap are noncontinuous.

The plants of this genus generally occur in clusters or clumps, arising from decayed wood on or under the ground.

Hypholoma appendiculatum. (Edible.)

Cap rather thin, ovate, then expanded until somewhat flattened, when damp dark brown, tawny when dry, slightly wrinkled and atomate; **flesh** white; **gills** crowded, somewhat adnate, white, at length purplish brown; **stem** white, hollow, equal, smooth, pruinose at apex; **veil** white, delicate, attached to the margin of the cap for a short time.

Cap 2 to 3 inches broad; stem 2 to 3 inches long, 2 to 3 lines thick. (Pl. XXVII, fig. 2; from G. F. Atkinson.)

Specimens of this species may be collected in the late spring, in summer, and frequently in the early fall. The plants are fragile and hygrophanous, scattered, clustered, or densely tufted. They grow on rotten logs, stumps, or sometimes on the ground, arising mostly from rotten wood beneath the surface.

This species is tender and possesses excellent esculent qualities. Drying and preserving for winter use have been recommended, as the flavor is retained to a remarkable degree.

Hypholoma perplexum. (Edible.)

Cap convex, expanding to nearly plane, sometimes umbonate, smooth, reddish or brownish red, margin yellowish; **flesh** white or whitish; **gills** thin, close, rounded at inner extremity, first pale yellow then greenish, later purplish brown; **stem** equal, hollow, fibrillose, yellowish above, reddish brown below.

Cap 1 to 3 inches broad; stem 2 to 3 inches long, 2 to 4 lines thick.

Hypholoma sublateritium and *H. perplexum* are very closely related and by some authorities the latter is regarded as only a variety of *H. sublateritium*, while certain mycologists consider the two species identical. Prof. Peck states that *H. perplexum* may be distinguished by its smaller size, more hollow stem, the yellow-greenish and purplish tints of the gills, and the absence of a bitter flavor. Like *H. sublateritium*, this species occurs abundantly in the fall about stumps or logs, often continuing until freezing weather. The plants grow in clusters and the caps are frequently discolored by the falling spores.

Hypholoma sublateritium. (Edible.)

Cap conical, becoming almost plane, fleshy, firm, smooth, but with fine, silky fibers, brick red, sometimes tawny, margin of lighter color; **flesh** white or yellowish; **gills** narrow, crowded, adnate, sometimes decurrent by a tooth, creamy when young, purplish olivaceous, sometimes with a sooty tinge when mature; **stem** firm, stuffed, attenuated downward, smooth or fibrillose, scaly, light yellowish, rust colored below; **veil** at first white, becoming dark, and may for a time adhere to the margin of the cap.

Cap 2 to 3 inches broad; stem 3 to 4 inches long, 3 to 5 lines thick. (Pl. XXVII, fig. 1; from G. F. Atkinson.)

This species appears very abundantly in the fall, producing large clusters around rotten stumps or decayed prostrate logs. The European form of this plant is reported as bitter and regarded as poisonous. The American form has been frequently eaten, although it has little to recommend it as a delicacy. Catsup has been made from it, but the success of the experiment was doubtless due more to the addition of condiments than to the flavor of the mushrooms.

COPRINUS.

The genus Coprinus is easily recognized by the black spores and the close gills, which at maturity dissolve into an inky fluid. The stem is hollow, smooth, or fibrillose. The volva and ring are not generic characters, but are sometimes present. The plants are more or less fragile and occur on richly manured ground, dung, or rotten tree trunks. The genus contains species of excellent flavor and delicate consistency.

Coprinus atramentarius. Inky cap. (Edible.)

Cap ovate, slightly expanding, silvery to dark gray or brownish, smooth, silky or with small scales, especially at the center, often plicate and lobed with notched margin; **gills** broad, ventricose, crowded, free, white, soon changing to pinkish gray, then becoming black and deliquescent; **stem** smooth, shining, whitish, hollow, attenuated upward, readily separating from the cap; **ring** near the base of stem, evanescent.

Cap 1½ to 4 inches broad; stem 2 to 4 inches long, 4 to 6 lines thick. (Pl. XXVIII.)

This species appears from spring to autumn, particularly after rains. It grows singly or in dense clusters on rich ground, lawns, gardens, or waste places. It has long been esteemed as an edible species. *Coprinus atramentarius* differs from *C. comatus* in the more or less smooth, oval cap and the imperfect, basal, evanescent ring.

Coprinus comatus. Shaggy mane. (Edible.)

Cap oblong, bell shaped, not fully expanding, fleshy at center, moist, cuticle separating into scales that are sometimes white, sometimes yellowish or darker, and show the white flesh beneath, splitting from the margin along the lines of the gills; **gills** broad, crowded, free, white, soon becoming pink or salmon colored and changing to purplish black just previous to deliquescence; **stem** brittle, smooth or fibrillose, hollow, thick, attenuated upward, sometimes slightly bulbous at base, easily separating from the cap; **ring** thin, movable.

Cap usually $1\frac{1}{2}$ to 3 inches long; stem 2 to 4 inches long, 4 to 6 lines thick. (Pl. XXII, fig. 2.)

This species has a wide geographical distribution and is universally enjoyed by mycophagists. The fungus is very attractive when young, often white, again showing gray, tawny, or pinkish tints. It appears in the spring and fall, sometimes solitary, sometimes in groups, on lawns, in rich soil, or in gardens.

Coprinus fimetarius.

Cap at first cylindrical, later conical to expanded, margin splitting, revolute or upturned, grayish to bluish black, surface at first covered with white scales, finally smooth; **gills** black, narrow; **stem** fragile, white, squamulose, hollow, but solid and bulbous at the base.

Cap 1 inch or more across, stem 3 or more inches high. (Pl. XXIX, fig. 1.)

This is a very common and abundant species on manure or rich soil and occurs from spring to winter. It is edible and considered excellent.

Coprinus micaceus. Mica inky cap.

Cap ovate, bell shaped, light tan to brown, darker when moist or old, often glistening from minute, micalike scales, margin closely striate, splitting, and revolute; **gills** narrow, crowded, white, then pink before becoming black; **stem** slender, white, hollow, fragile, often twisted.

Cap 1 to 2 inches broad; stem 2 to 4 inches long and 2 to 3 lines thick. (Pl. XXX, fig. 1; from Geological and Natural History Survey of Connecticut.)

This glistening little species occurs very commonly at the base of trees or springing from dead roots along pavements, or more uncommonly on prostrate logs in shady woods. The plants appear in great profusion in the spring and early summer, and more sparingly during the fall. *Coprinus micaceus* is a very delicious mushroom and lends itself to various methods of preparation.

PSATHYRELLA.

The species comprising the genus Psathyrella are all fragile, having thin membranaceous, striate caps. When young the margin of the cap lies against the stem, but never extends beyond the gills, which are sooty black and not mottled like those of Panaeolus.

Psathyrella disseminata. (Edible.)

Cap thin, oval to bell shaped, yellowish, gray or grayish brown, minutely scaly, becoming smooth, sulcate or plicate, margin entire; **gills** broad, adnate, white, then gray, later black; **stem** hollow, slender, fragile.

Cap about one-half inch broad; stem 1 to $1\frac{1}{2}$ inches long, 1 to $1\frac{1}{2}$ lines thick. (Pl. XXIX, fig. 2; source of photograph unknown.)

This is a delicate little species, appearing on decaying wood or about old roots of trees. It occurs from May until frost, often intermittently from the same center. The species is edible, but has too little substance to render it a popular article of diet.

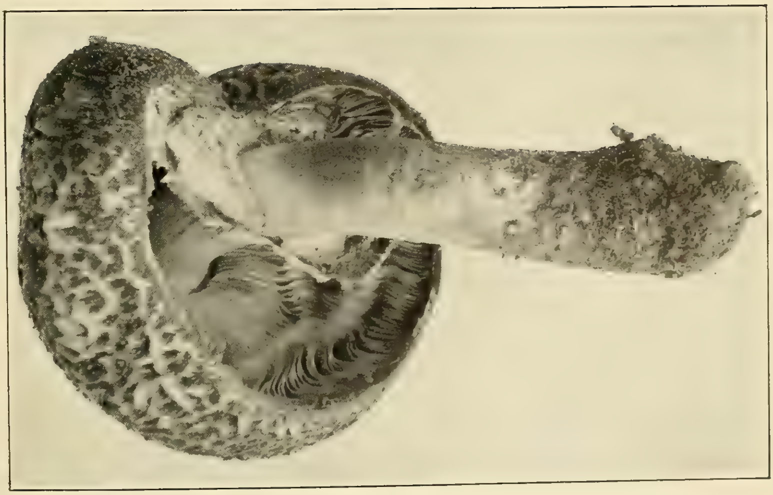

FIG. 1.—AGARICUS PLACOMYCES. (EDIBLE.)

FIG. 2.—STROPHARIA SEMIGLOBATA.

FIG. 1.—AGARICUS SUBRUFESCENS. (EDIBLE.)

FIG. 2.—AGARICUS SUBRUFESCENS, SHOWING HABITAT. (EDIBLE.)

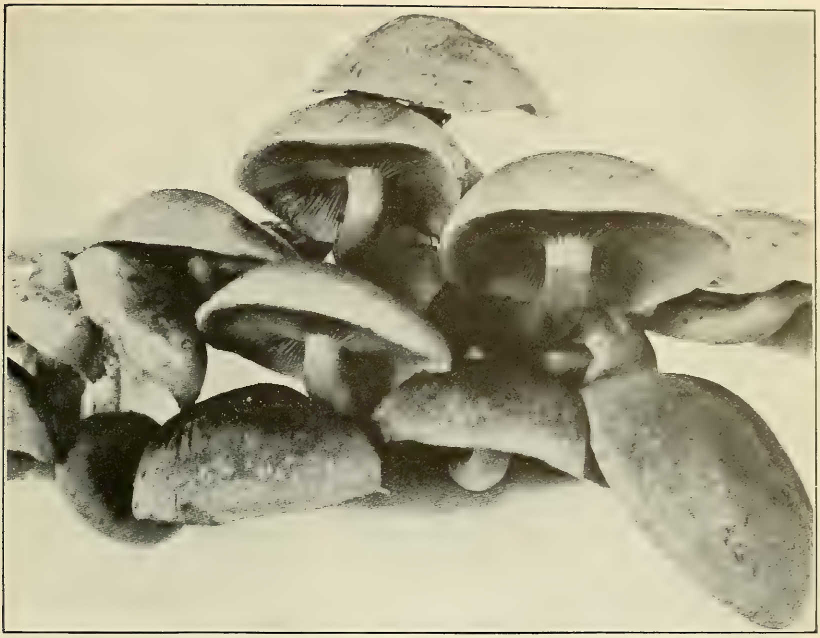

FIG. 1.—HYPHOLOMA SUBLATERITIUM. (EDIBLE.)

FIG. 2.—HYPHOLOMA APPENDICULATUM. (EDIBLE.)

COPRINUS ATRAMENTARIUS. (EDIBLE.)

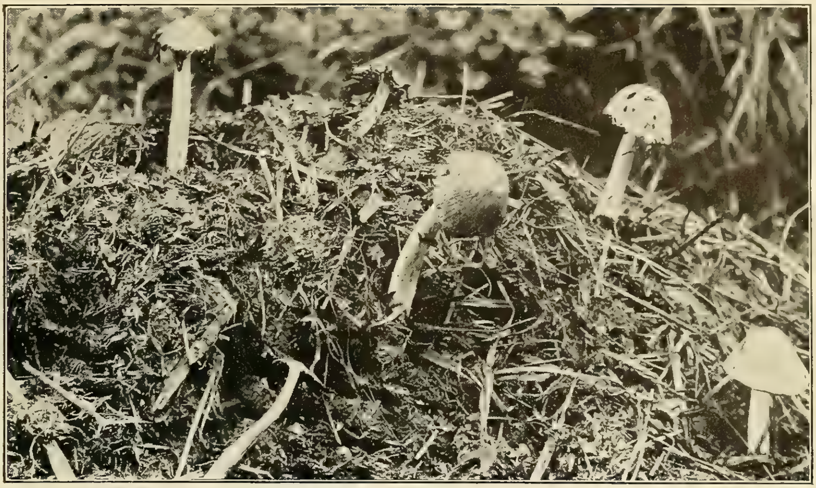

FIG. 1.—COPRINUS FIMETARIUS. (EDIBLE.)

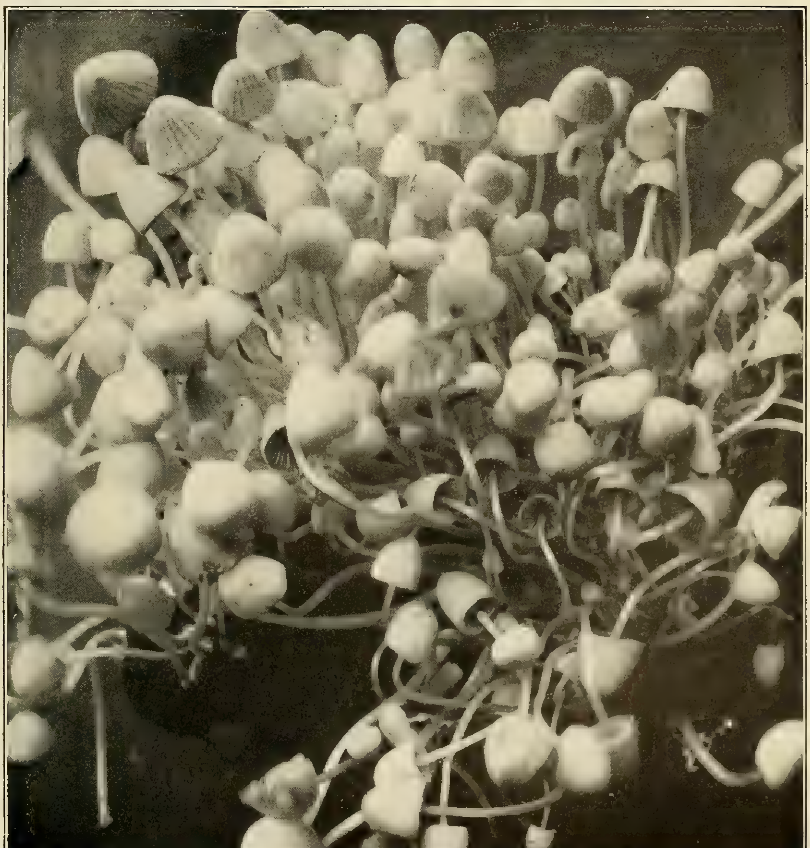

FIG. 2.—PSATHYRELLA DISSEMINATA. (EDIBLE.)

FIG. 1.—COPRINUS MICACEUS. (EDIBLE.)

FIG. 2.—PANAEOLUS RETIRUGIS. (EDIBLE.)

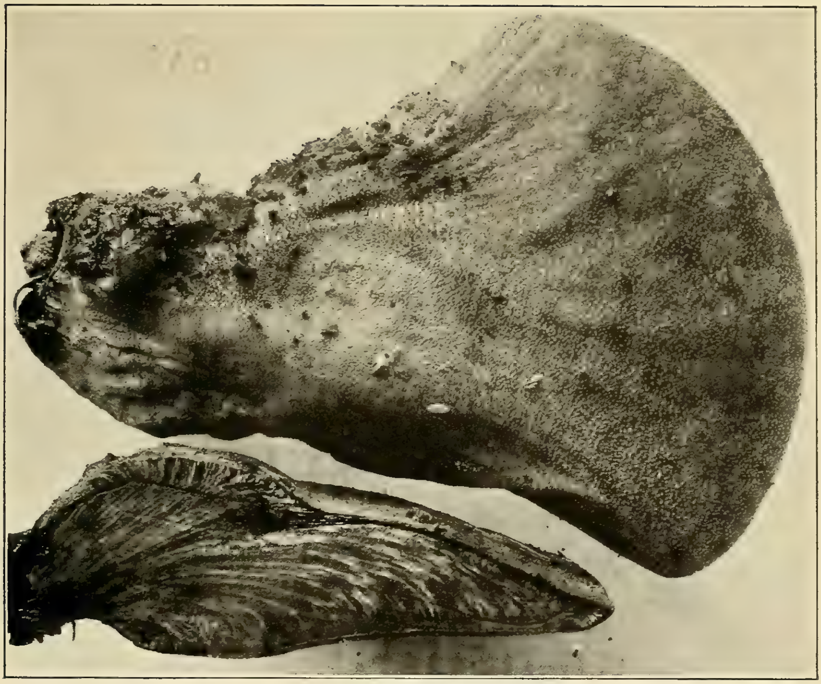

FIG. 1.—FISTULINA HEPATICA. (EDIBLE.)

FIG. 2.—BOLETUS FELLEUS.

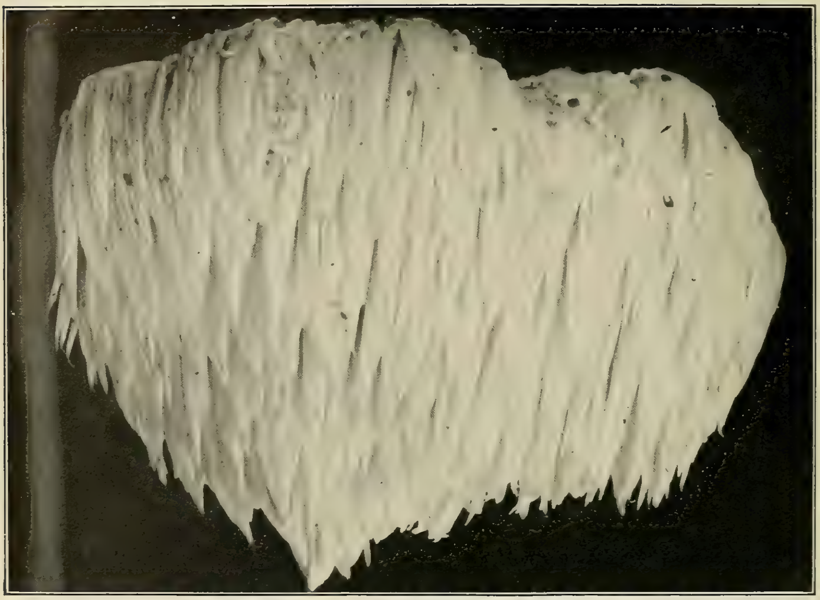

FIG. 1.—HYDNUM ERINACEUM. (EDIBLE.)

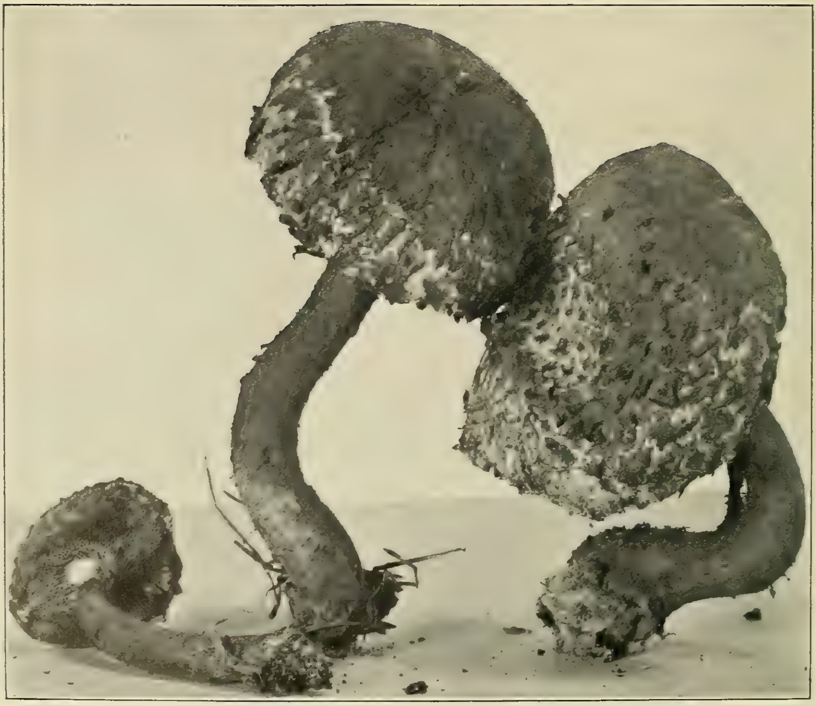

FIG. 2.—STROBILOMYCES STROBILACEUS.

PANAEOLUS.

In the genus Panaeolus the cap is slightly fleshy and the margin nonstriate, always extending beyond the gills, which are gray and mottled from the falling of the black spores. The stem is without a ring and polished. The two nearest related genera are Psathyrella and Coprinus. From the first Panaeolus is separated by the nonstriate margin of the cap and from Coprinus by the nondeliquescent gills.

Panaeolus retirugis. (Edible.)

Cap ovate, conic, slightly expanding, almost hemispherical, cream to tan colored, becoming grayish and dark smoky, viscid in wet weather, irregularly marked with anastomosing wrinkles; remnants of **veil,** which is prominent and firm in young plants, adhering as fragments on margin of mature caps; **gills** rather broad, ascending, adnexed, grayish to violet black; **stem** color of cap, darker in lower part, hollow, smooth, granulate, may be slightly bulbous.

Cap three-fourths inch to 1½ inches broad; stem 2 to 4 inches long, 2 to 3 lines thick. (Pl. XXX, fig. 2.)

This species is to be found on dung or on richly manured lawns. It seldom occurs in sufficient quantity to be cooked alone, but the flavor is pleasant and readily imparted to other mushrooms. The appendiculate character of the veil is of assistance in distinguishing this species from others of the genus.

POLYPORACEÆ (pore fungi).

Members of the family Polyporaceæ are characterized by the production of a poriferous fructification. In Agaricaceæ the spores are developed on gills, while in Polyporaceæ they are formed in numerous more or less minute tubes on the lower surface of the fruiting body (hymenophore). The tubes may be short or elongated, the mouths (pores) round, angular, or compressed.[1] In some genera the hymenium is wrinkled and the tubes are reduced to mere pits. Great variation is also to be observed in the consistency of the fruiting body; it may be woody, fleshy, coriaceous, or subgelatinous. The key that follows will aid in distinguishing the genera of Polyporaceæ discussed in this paper.

Key to Polyporaceæ.

Hymenophore normally pileate, sometimes with resupinate forms;
- Stratum of tubes easily separable from the hymenophore, stem central—
  - Cap smooth.......... BOLETUS.
  - Cap with large scales.......... STROBILOMYCES.
- Stratum of tubes distinct from the hymenophore, but not separable from it—
  - Tubes in several layers, woody, perennial.......... FOMES.
  - Tubes not stratose—
    - Cap thick.......... POLYPORUS.
    - Cap thin.......... POLYSTICTUS.
    - Cap fleshy, tubes crowded.......... FISTULINA.

[1] The tubes and contour of the mouths may be readily determined by the aid of a small hand lens.

Hymenophore sessile, corky, tubes sinuous and labyrinthiform.......DAEDALEA.
Hymenophore reflexed, resupinate or amorphous, subgelatinous, hymenium plicate or rugose porous.................................MERULIUS.

BOLETUS.

In general appearance, namely, the pileate and stipitate character of the plants, the species of the genus Boletus resemble members of the Agaricaceæ. The important difference is the fact that the spores, instead of being developed on gills, are borne in numerous small tubes, which are closely crowded but easily separable from one another and from the hymenophore.

Most of the plants of this genus are terrestrial, but occasionally they are to be found growing upon wood. Some species are edible and considered exceedingly good, while others are extremely dangerous. The phenomenon of changing color on exposure to air exhibited by certain species is not a character peculiar to either poisonous or edible varieties.

Key to species of Boletus.

Surface of hymenium yellow, orange, or greenish.
- Ring present:
  - Cap yellow...*B. luteus.*
  - Cap brown when moist, yellowish when dry—
    - Stem long, granulated...............................*B. granulatus.*
    - Stem short, not or rarely granulated....................*B. brevipes.*
- Ring absent:
  - Flesh not changing color—
    - Mouths of tubes white becoming tinged with flesh color...*B. felleus.*
    - Mouths of tubes white becoming yellow and greenish.....*B. edulis.*
  - Flesh or tubes or both changing color—
    - Tubes adnate or sinuate, depressed, tinged with green....*B. badius.*
    - Tubes free, yellow, mouths bright red, orange colored in age...*B. satanus.*
    - Tubes subadnate, large, angular, flesh red immediately beneath the cuticle, changing to blue where wounded.*B. chrysenteron.*
    - Tubes adnate, small, subrotund, bright yellow, changing to blue where wounded.............................*B. bicolor.*

Boletus bicolor. (Edible.)

Cap convex, glabrous, pruinose, dark red, paler in age and sometimes spotted with yellow, firm; **flesh** yellow, sometimes changing to blue where wounded; **tubes** nearly plane, adnate, bright yellow, changing to blue where wounded, mouths small angular or subrotund; **stem** subequal, solid, red, generally yellow at the top.

Cap 2 to 4 inches broad; stem 1 to 3 inches long.

A very attractive little species, occurring quite commonly in Virginia and Maryland in the woods and on lawns in shady places. It is considered one of the best edible species.

Boletus chrysenteron.

Cap convex or plane, brown or brick red, more or less cracked, subtomentose; **flesh** yellow, red immediately beneath the cuticle, slightly changing to blue where wounded; **tubes** subadnate, yellow then greenish, large, angular; **stem** fibrous, equal, red or yellowish.

Cap 1 to 3 inches broad; stem 1 to 3 inches long.

Authors differ concerning the edibility of this species; consequently extreme caution should be used to avoid collecting it for *Boletus bicolor*, which is edible.

Boletus edulis. (Edible.)

Cap convex to expanded, smooth, firm when young, becoming soft in age, the color varying from grayish red to brownish red, generally paler on the margin; **flesh** white or yellowish, sometimes reddish beneath the cuticle; **tubes** convex, nearly free, long, minute, white, then yellow and greenish; **stem** variable in length, straight or flexuous, equal or bulbous, more or less reticulated, whitish, pallid, or brownish.

Cap 4 to 6 inches broad; stem 2 to 6 inches long.

A species of frequent occurrence and the one most commonly eaten of this genus.

Boletus felleus.

Cap convex or nearly plane, firm, becoming soft, color variable, pale yellowish, grayish brown, reddish brown, or chestnut; **flesh** white, often changing to flesh color when wounded, taste bitter; **tubes** adnate, long, depressed around the stem, mouths angular, white, becoming tinged with flesh color; **stem** similar in color to the cap, but paler, variable, long or short, equal or tapering upward, sometimes bulbous, reticulated above.

Cap 3 to 4 inches broad; stem 2 to 3 inches long. (Pl. XXXI, fig. 2.)

This is a common and widely distributed species. It is exceedingly attractive on account of its color, size, and solidity; though not poisonous, it is so bitter that a small quantity renders a whole dish unpalatable.

A variety, *Boletus felleus obesus*, attains a size of about a foot in diameter and has coarse reticulations on the stem.

Boletus granulatus.

Cap convex or nearly plane, viscid or glutinous and rusty brown when moist, yellowish when dry; **flesh** pale yellow; **tubes** short, adnate, yellowish, mouth granulated; **stem** pale yellowish, dotted above.

This species is considered edible by most authors, but it is not attractive on account of the viscid character of the cap.

A nearly related species, *Boletus brevipes*, is distinguished from *B. granulatus* by a shorter stem and the absence of granulations on the mouths of the tubes.

Boletus luteus. (Edible.)

Cap convex, becoming nearly plane, viscid or glutinous when moist, dull yellowish to reddish brown, sometimes streaked or spotted; **flesh** whitish or dull yellowish; **tubes** adnate, minute, yellow becoming darker with age; **stem** stout, pale yellowish, brownish or reddish, dotted above the annulus; annulus variable, sometimes persisting as a narrow ring and again appearing as a broad collar.

Cap 3 to 4 inches broad; stem $2\frac{1}{2}$ to 3 inches high.

An excellent edible species of wide geographic distribution, occurring commonly in pine woods.

A very similar species is *Boletus subluteus*, which is ornamented with dots both above and below the annulus. This fungus is also considered edible.

STROBILOMYCES.

The genus Strobilomyces closely resembles Boletus, but it may be distinguished by the less easily separable tubes and extremely scaly cap and stem.

Strobilomyces strobilaceus.

Cap hemispherical or convex, shaggy from numerous coarse, blackish scales, margin more or less appendiculate from the scales and fragments of the veil, which covers the tubes in the young plant; **flesh** at first whitish, changing to reddish, then blackish where wounded; **tubes** adnate, at first whitish, becoming blackish with age, mouths large, angular, changing color like the flesh; **stem** even or tapering above, sulcate at the top, scaly, colored like the cap.

Cap 2 to 4 inches broad; stem 3 to 5 inches long, 4 to 10 lines thick. (Pl. XXXII, fig. 2.)

This fungus occurs commonly in woods and along roadsides, singly, in small groups, or occasionally cespitose, from early summer until autumn. It is considered edible, but is not attractive.

FOMES.

The genus Fomes is distinguished among the Polyporaceæ by the hard, woody character of the species. The hymenophore is bracket shaped; the tubes are much elongated and stratified, one stratum developing annually. Fomes contains no edible species, but comprises many serious tree-destroying forms.

Fomes applanatus.

Cap smooth, cinnamon brown, becoming hoary, horizontal, flattened, shelflike, concentrically zoned, semicircular, broadly attached, margin thickened, first white, later becoming brown; hymenium flat, pores small, mouth white, changing to brown when bruised; internal structure of fibrous-spongy texture, brown in color.

Cap $2\frac{1}{2}$ to 8 inches broad, 2 inches or more thick.

This species is perennial and of common occurrence on various deciduous trees.

Fomes lucidus.

Cap horizontal, irregularly kidney shaped, blood red, surface uneven, coarsely grooved, polished, corky, light in weight; **stem** lateral, length variable, polished, same color as the cap; **tubes** small, white, then tan.

Cap 2 to 6 inches broad.

This fungus is of wide distribution and quite common occurrence, appearing on logs and trunks. It is easily recognized on account of the varnished appearance of the cap and stem.

POLYPORUS.

Species belonging to the genus Polyporus present considerable variation in stem, form, and texture. The stem may be central, excentric, or absent, the hymenophore circular, reniform, or hoof shaped, azonate or grooved, and the substance fleshy, soft, corky, or woody. This genus is distinguished from Polystictus by the thicker cap and from Fomes by the nonstratose pores. Species of this genus are widely distributed, and representatives may be found from the North to the Tropics. Polyporus contains a few edible species and many wound parasites, species injurious to economic and ornamental trees. Wound parasites are fungi which have gained entrance to the interior of a tree or host through some unprotected surface resulting from lightning, insect attack, injudicious pruning, or some other agency.

Polyporus betulinus.

Hymenophore tough and fleshy, then corky, hoof shaped, umbonate at point of attachment, margin thickened, obtuse incurved, white when young, later brown to brownish red, zoneless, smooth; **pores** minute, short, unequal, whitish.

This fungus is of common occurrence on birch trees, measuring from 3 to 8 inches or more in width. When young it is considered edible, but possesses a rather strong flavor. It is often used as material for outdoor sketching, for which purpose it is very well adapted.

Polyporus frondosus.

This species occurs in large tufts, which measure 6 inches to over a foot in breadth. The **caps** are very numerous, crowded and overlapping, 1 to 2 inches in diameter, irregular in shape, curved, repand, lobed or cleft, brown or sooty gray; **stems** indefinite, branching or confluent; **pores** very small, white.

A very common plant, growing about stumps, roots, and trunks. It is edible, tender when young, but soon becomes tough.

Polyporus gilvus.

This plant possesses no value as an article of diet, but as a species frequently encountered by collectors its identity is of interest. Its specific name refers to the color, and the fungus is often referred to as the rust-brown Polyporus. The **caps** vary from 2½ to 4½ inches in width; the **pores** are brown, round, and minute.

Polyporus sulphureus.

This is a very conspicuous fungus on account of its large clusters and the characteristic sulphur-yellow color of the species. The **caps** are fleshy, spongy, attached laterally, very much imbricated, more or less fan shaped, smooth, even when young, later ridged and furrowed; margin at first thick and blunt, becoming thinner; **pores** very small, plane, and sulphur yellow.

This species occurs abundantly and is edible, though of doubtful value. It is of interest as a wound parasite on various trees, gaining access to the interior of a tree through an exposed surface and finally causing the death of the host.

POLYSTICTUS.

Species of the genus Polystictus may be distinguished from those of Polyporus by being thinner and more pliant. None are to be especially recommended for table purposes, but by their abundance and attractiveness they force themselves upon the attention of the amateur or any one interested in natural history. All the species described here are sessile and shelving.

Polystictus cinnabarinus.

The specific name of this plant is derived from its bright cinnabar color. The fungus is shelving, pliant, and rather thicker than the following species. It grows on dead logs or dead branches of various trees.

Caps 1 to 3 inches in width.

Polystictus pergamenus.

This fungus is thin and very pliant when fresh, somewhat tomentose, with indistinct, longitudinal color zones. The **tubes** are violet or purplish, but the plants are easily weathered and the tubes become lacerated, resembling Irpex, a genus possessing teeth instead of tubes.

Caps 1 to 1½ inches in width.

Polystictus versicolor.

Polysticus versicolor is easily distinguished by the concentric bands of different colors, mostly bay or black, which mark the cap. The **tubes** are white, and the margin thin, sterile, and entire. The plants grow densely imbricated and are to be found abundantly on dead stumps or trunks of many varieties of trees.

Caps three-fourths inch to 1½ inches in width.

FISTULINA.

In the genus Fistulina the stem is lateral or very short, the fruiting body growing horizontally from trunks of living trees or stumps of recently cut trees. It is distinguished from Boletus and Polyporus by the tubes, which are separate from one another and closed at the mouth when young.

Fistulina hepatica. Beefsteak fungus. (Edible.)

Specimens of this species are always shelving and may be sessile or stipitate. The **caps** are subspatulate, the margin entire, wavy or scalloped, blood red, and at maturity marked with more or less radiating lines. The **flesh** is red, thick, soft, juicy, and traversed by tenacious fibers. The **tubes** are at first short and yellowish, becoming elongated and discolored in age.

Caps 3½ to 8 inches broad, reported as attaining in England a weight of 30 pounds. (Pl. XXXI, fig. 1; from C. G. Lloyd.)

This fungus is variously known as the beefsteak fungus, beef tongue, oak tongue, or chestnut tongue. It grows from decaying crevices of certain deciduous trees, such as the oak and chestnut, but preferably the chestnut. This species is widely distributed and has an international reputation for its edibility.

DAEDALEA.

The plants belonging to the genus Daedalea are sessile, dry, and corky. The species are exceedingly interesting on account of the hymenophore, which shows intermediate stages between the gill and pore fungi. The pores are typically sinuous and labyrinthiform, but often the thick platelike developments simulate gills more than pores. Several species are of common occurrence, but all are tough and corky and none reported edible.

Daedalea quercina.

Cap shelflike, dimidiate, triangular in cross section, corky, rigid, smooth or nearly so, wrinkled, grayish to light brownish, margin usually thin, pallid; **pores** wavy, some gill-like.

Caps 2 to 4½ inches or more in width.

This species occurs on oak (Quercus) stumps and trunks, and because of its habit of growing on this host it was named *Daedalea quercina.*

MERULIUS.

The species of the genus Merulius are resupinate and subgelatinous. The hymenium is wrinkled or foldlike and the pores are very shallow.

Species of Merulius are very troublesome and destructive in dwellings constructed wholly or in part of timber. Attacks by these fungi are common where the light and ventilation are poor, as in cellars, basements, and similar places.

Merulius lacrymans.

In *Merulius lacrymans* the fruiting body is flat, prostrate, soft, and characterized by watery exudations. It is at first white, then red, later changing to yellowish brown. This is one of the most common species which attacks timber and renders it spongy, watery, and unfit for building purposes. The mycelium may develop as long strands, or it may form large sheets which peel off readily.

HYDNACEÆ.

The plants in the Hydnaceæ are stipitate, bracket shaped or resupinate, fleshy, corky, leathery, or woody. In Hydnum, the most highly developed genus of this family, the hymenium is distinctly toothlike, but there are many intermediate gradations, from scattered granules or small hemispherical prominences to toothlike developments. In all having teeth, the processes are directed downward.

Key to Hydnaceæ.

Hymenium of distinct, awl-shaped teeth or spines, resupinate or with central stem:
- Plants fleshy........ HYDNUM.
- Plants woody........ ECHINODONTIUM.

Hymenium with teeth united (connected at the base by slightly raised folds), teeth not so acute as in Hydnum........ IRPEX.

Hymenium with coarse, blunt tubercles, subcylindrical, resupinate.. RADULUM.

HYDNUM.

The species of the genus Hydnum vary greatly as to form, consistency, and manner of growth. Certain forms possess well-defined cap and stem, some are bracket shaped or shelving and still others are resupinate. The teeth are pointed and free from each other at the base. In consistency, species of Hydnum range from soft fleshy to almost woody. They may be terrestrial in habit or may grow on living or dead trees.

Hydnum coralloides. (Edible.)

This species is easily recognized by the long, interlacing tapering branches, which are of two kinds: The primary, which are nearly sterile; and the secondary, which are fertile and chiefly bear the slender terete teeth. The substance is fleshy, brittle to somewhat tough. *Hydnum coralloides* is one of the most graceful and beautiful species of fungi, and its white, corallike tufts measure from 6 to 18 inches across. It grows on standing or prostrate timber in a stage of decay and is found from August until frost. It is edible, but not very abundant or common.

Hydnum erinaceum. Satyr's beard. (Edible.)

This species forms pendulous tufts from 2 to 10 inches across. The point of attachment is small and the mass generally projects horizontally from the substratum. The tufts are white, changing to yellowish brown in drying. The individual teeth are crowded, slender, terete, tapering acute, 1 to 2½ inches long. This species is quite conspicuous, often growing from crotches or wounds of trees—beech, oak, locust, etc. (Pl. XXXII, fig. 1.)

Hydnum imbricatum.

In this species the plants are terrestrial and provided with a stipe. The **cap** is convex and nearly expanded, fleshy in the center, thinner toward the margin, surface scaly, especially toward the center. The scales may be imbricated, sometimes zonately arranged, or the flesh broken up in a tessellated manner. The cap varies from mouse color to dark brown, with the stem of the same color. The **teeth** are coarse, terete, tapering, light brown to ashy. *Hydnum imbricatum* is of fairly wide geographic range and grows on the ground, especially in pine and chestnut woods. It is edible, but slightly bitter. (Pl. XXXIII, fig. 1; from F. E. Clements.)

Hydnum repandum.

This species is also terrestrial and the stem central or excentric. The **cap** is more or less irregular, margin repand or wavy, color variable, ranging from light buff to brown or reddish; **flesh** whitish, compact, and fragile. The **teeth** are white, conical, and brittle. The **stem** is thick, even or clavate. *Hydnum repandum* is quite common and may be found from July to November in woods on the ground, or sometimes on much-decayed stumps. It is edible and considered very good.

Hydnum septentrionale.

In this species the **caps** are shelving, imbricated, and arranged in horizontal layers, smaller at the top and bottom and larger in the center. The surface is irregular, somewhat rugose, azonate, and white to brownish. The **spines** are crowded, terete to subangular, one-half to three-fourths inch long. This species occurs on various deciduous trees (Fagus, Acer, Ulmus, Nyssa), often attaining considerable size. The edges of the young plant are said to be edible, but they have little flavor. (Pl. XXXIII, fig. 2.)

IRPEX.

The genus Irpex has no species of great interest to the mycophagist, but several common forms are apt to attract the attention of the amateur collector. Irpex may be distinguished from the preceding genus by the teeth being connected at the base and being less awl shaped than in Hydnum.

Irpex fusco-violaceus.

The plants of this species are grayish, effuso-reflexed, thin, and coriaceous; **teeth** in irregular rows, platelike, incised at the apex, violet brown. The technical description of this fungus mentions the silky character of the cap, but most specimens appear tomentose or tomentose-villose. *Irpex fusco-violaceus* is very common on decaying coniferous trees.

TREMELLACEÆ (jelly fungi).

Members of the family Tremellaceæ are typically gelatinous or sometimes waxy, horny when dry, reviving when wet. The plants are irregular in form, almost amorphous, usually stemless, globose or brainlike. The hymenium is smooth; that is, does not develop into gills, tubes, or teeth, except in one genus, Tremellodon. Most of the forms are found on wood; some are edible but not especially good.

Key to Tremellaceæ.

Fruiting body membranaceous, rigid and cartilaginous when dry, reviving when moist, hymenium gelatinous, ear shaped, attached to a narrow base.......................................HIRNEOLA.

Fruiting body cerebriform, or forming foliaceous, sessile tufts........TREMELLA.
Fruiting body cup shaped or forming irregular masses................EXIDIA.
Fruiting body substipitate, somewhat spatulate, bifurcate, gelatinous, cartilaginous, the two surfaces different, hymenium unilateral......GUEPINIA.
Fruiting body very gelatinous, bearing crowded, acute spines on the under surface..TREMELLODON.

HIRNEOLA.

Species of the genus Hirneola are irregularly cup shaped, earlike, soft and subgelatinous when wet, horny when dry, veined or wrinkled.

Hirneola auricula-judae.

This species is commonly known as Jew's-ear, on account of its resemblance to the human ear. It occurs singly or grouped, and varies in size from 1 to 2 inches across, and in color from brown to black. *Hirneola auricula-judae* is found on decaying wood of various trees, but is reported as exhibiting a preference for elms. It is extensively used in China, where it is made into soup. (Pl. XXXIV, fig. 2; from C. G. Lloyd.)

TREMELLA.

In the genus Tremella the substance is gelatinous, tremulous, convoluted, or effuse, and the hymenium covers the entire upper surface of the plant. The species are most commonly found growing on rotting wood, sometimes on the ground, and occasionally parasitically, as, for instance, the species *Tremella mycetophila* on *Collybia dryophila*. Members of this genus are reported as harmless, but as their water content is large and their nutritive value small, they are not to be highly recommended as an article of diet.

Tremella frondosa.

This species consists of many contorted, twisted, leaflike lobes, united at the middle and base. It is described as pinkish yellow, but the collector will often find it cream buff. *Tremella frondosa* is said to be the largest species of the genus, often attaining a size of 4 to 6 inches in diameter and slightly less than that in height. It occurs during the summer and early fall on decaying wood.

EXIDIA.

The species of most common occurrence in this genus is *Exidia glandulosa,* commonly called witches' butter. In wet weather it appears as an exceedingly gelatinous, amorphous mass, brown to black in color, and varying in size from one-half to 1 inch in width. In dry weather it persists as a black incrustation on fallen limbs or trunks. It is an autumnal species, but persists through the winter.

GUEPINIA.

The species of the genus Guepinia are gelatinous when moist and cartilaginous when dry. In the latter condition they are shriveled and very much reduced in size. The hymenium is developed on only one side of the sporophore.

Guepinia spathularia.

In rainy or damp weather this little fungus forces itself upon the attention of the collector. It occurs abundantly, especially upon railroad ties. Plants arise from a stemlike base, are spatulate, lobed, and branched, one-half to 1 inch in height, yellow or orange. In damp weather they are subgelatinous to membranaceous, in dry weather horny to cartilaginous. After a rain these little fungi appear suddenly and are conspicuous, but they soon shrivel, becoming insignificant. The species has no value from an epicurean point of view.

TREMELLODON.

The genus Tremellodon can not be confused with any other, as it is the only gelatinous spiny fungus known.

Tremellodon gelatinosum.

Specimens are somewhat stipitate, tremulous, dimidiate, fan shaped; **cap** opalescent, roughened with small dots; **teeth** soft, white. They grow on decaying logs in damp woods in the fall and early winter, and are considered delicious when slowly stewed.

CLAVARIACEÆ (coral fungi).

In the family Clavariaceæ the plants are erect, simple, mostly club shaped, and variously branched. The hymenium covers both the side and upper surfaces.

Many beautiful plants belong to this family, which owes its name to the corallike appearance of many of its species. The color also adds to the beauty of the plants, which may be lavender, orange, yellow, pink, red tipped, cream, or white. Many species are edible; but, since cases of poisoning have been reported, the indiscriminate eating of Clavariaceæ is not to be advised.

Key to Clavariaceæ.

Plants much branched, branches compressed, platelike, crisped .... SPARASSIS.
Plants club shaped and simple or variously branched, stem not distinct from the hymenophore .... CLAVARIA.

Sparassis crispa. Leaf coral. (Edible.)

This fungus forms a rosette, or tuft, which springs from a thick, rootlike base, and is composed of flat, thick, leaflike, revolute, white, or yellowish branches. The specific name was suggested by the curly character of the branches. Specimens are gelatinous waxy in consistency and retain their form fairly well when dried. The species is considered very delicious.

The plants vary from 4 to 10 inches broad and 2½ to 7 inches high.

Clavaria pistillaris. (Edible.)

Clavaria pistillaris, unlike many species of Clavaria, is not crowded or corallike. It consists of a club-shaped body, yellowish, ochraceous, or brownish, with flesh white and spongy and exterior smooth or wrinkled.

It grows to a height of 2 to 6 inches or more and is 1 or more inches thick.

This fungus is found growing in mixed woods, preferably damp, mossy locations, and by some authorities is considered one of the best edible varieties.

GASTEROMYCETES.

Key to Gasteromycetes.

Developed under ground, at first inclosed in a universal volva consisting of three distinct layers, the outer firm and elastic, the second gelatinous, and the inner thin and delicate................PHALLACEÆ.
Developed above ground, peridium consisting of two or more distinct layers, usually globose to pyriform, with a mouth or irregular opening, spores a powdery mass at maturity with well-developed capillitium..LYCOPERDACEÆ.
Developed at the surface of the ground, peridium dehiscing irregularly by the splitting or decay of the upper part, capillitium absent..SCLERODERMACEÆ.
Developed above ground, peridium at first partly closed, funnel-shaped to cup shaped, containing one to many sporangioles.....NIDULARIACEÆ.

PHALLACEÆ (stinkhorn fungi).

Most of the species belonging to the family Phallaceæ are characterized by a disagreeable odor. The plants grow below the surface of the ground or on decayed stumps. The mycelium, or vegetative part, forms coarse, ropelike strands from which the fruit body arises and which in its early stages is commonly known as an "egg" because of its form. The outer part of the egg forms the volva and consists of outer and inner membranes, between which is a gelatinous substance. The central portion of the egg is occupied by a tubular receptacle or part bearing the gleba (hymenium). The receptacle elongates rapidly and at maturity ruptures the volva, thus exposing the spore-bearing mass. Species of this family have highly developed characters, such as color, taste, and odor, which, by attracting insects, insure the dissemination of the spores.

Key to Phallaceæ.

Receptacle with hanging cap:
  Gleba borne on a special cap—
    Stalk with an appendage extending below the cap..........DICTYOPHORA.[1]
    Stalk without an appendage.................................ITHYPHALLUS.
Receptacle without hanging cap:
  Gleba borne on the upper portion of the stalklike receptacle......MUTINUS.

DICTYOPHORA.

The name Dictyophora, meaning net bearer, is descriptive of the delicate netlike appendage, a character peculiar to this genus, but more or less conspicuous in the different species. The stalklike receptacle consists of spongy, cellular tissue. The species here discussed are of fairly wide and common occurrence.

[1] By some authorities, Dictyophora and Ithyphallus are described under the generic name Phallus, of which *Phallus impudicus* is the common type.

Dictyophora duplicata.

Dictyophora duplicata is from 6½ to 9 inches high, with cap about 2½ inches in diameter and the stem one-half to three-fourths inch in thickness. The **cap** is campanulate, and after the deliquescence of the gelatinous gleba appears recticulate pitted. The long white **veil**, which is sometimes entire but often torn and shreddy, is pendulent and consists of coarse, thick threads. *Dictyophora duplicata* is considered edible if used before the volva has ruptured, and when cut in slices and fried or stewed it is said to be fairly good. (Pl. XXXV, fig. 1; from J. B. Rorer.)

Dictyophora ravenelii.

This species is readily distinguished from the preceding by the more slender stem and the conico-bell-shaped **cap**, which is wrinkled after the disappearance of the gleba and does not present prominent reticulations. The **veil** is membranaceous and not conspicuously netlike, as in *Dictyophora duplicata*. (Pl. XXXVI, figs. 2 and 3; from G. F. Atkinson.)

ITHYPHALLUS.

The genus Ithyphallus is similar to Dictyophora, but differs in not having a netlike veil.

Ithyphallus impudicus.

The **volva** is globose or ovoid, white or pinkish, 2 to 3 divided. The **cap** is conic to campanulate, the surface reticulate pitted, apex smooth, and the stalk cylindric-fusiform, hollow, and widely perforate at the apex. This is a very common species, and is found in considerable numbers about dead stumps, fence corners, yards, etc. Its presence is readily detected by the strong, disagreeable odor which it emits when mature. Mr. C. G. Lloyd, from his study and observations of types, considers our American form a variety of *Ithyphallus impudicus* on account of the pink volva, and he states that we do not seem to have the type form with the white volva. (Pl. XXXVII, fig. 2.)

MUTINUS.

In the genus Mutinus the receptacle or stalk is cellular or spongy, simple, elongated, cylindric tapering, with the gleba-bearing portion definite. The species of Mutinus are very similar in general form and color, but are mainly separated by the character of the cellular structure of the receptacle and the separation between gleba and stem. The two species most commonly found are here described.

Mutinus caninus.

Stipe hollow, perforate or imperforate, fusiform, white or reddish; spore-bearing portion flesh colored, sharply defined, cellular structure not uniform; e. g., the cells or minute chambers composing the stem are larger than those of the gleba-bearing portion.

Mutinus elegans.

Stipe hollow, perforate, tapering from base, white or pinkish; spore-bearing part red not sharply defined, cellular structure uniform.

LYCOPERDACEÆ.

Key to Lycoperdaceæ.

Peridium with or without a sterile base, outer layer spiny, warty, or papery:
- Dehiscence regular by apical mouth .... LYCOPERDON.
- Dehiscence irregular .... CALVATIA.

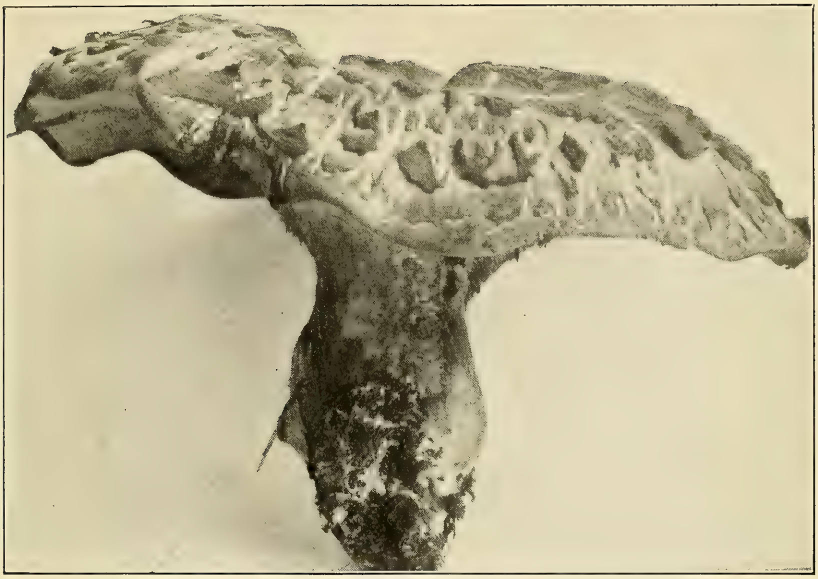

FIG. 1.—HYDNUM IMBRICATUM.

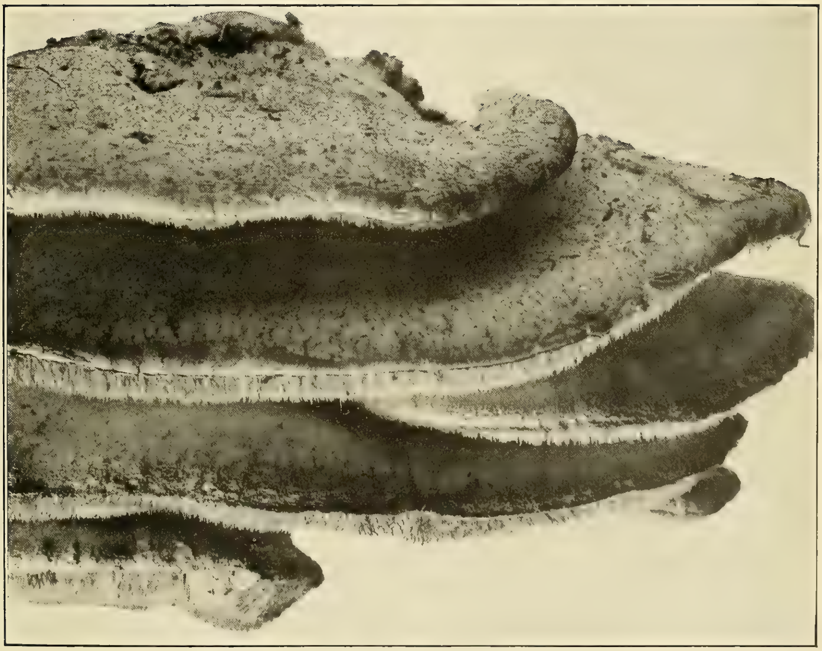

FIG. 2.—HYDNUM SEPTENTRIONALE.

FIG. 1.—LYCOPERDON PYRIFORME. (EDIBLE.)

FIG. 2.—HIRNEOLA AURICULA-JUDAE.

FIG. 1.—DICTYOPHORA DUPLICATA.

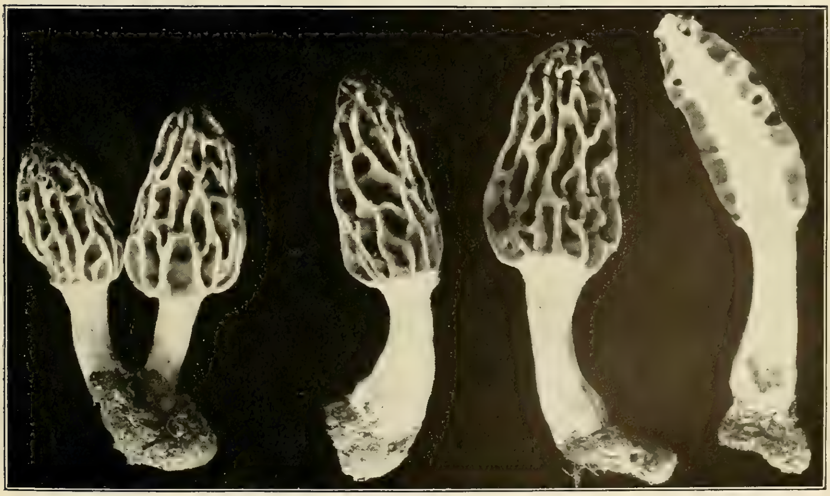

FIG. 2.—MORCHELLA ESCULENTA. (EDIBLE.)

FIG. 1.—GEASTER RADICANS.

FIG. 2.—DICTYOPHORA RAVENELII (MATURE SPECIMEN).

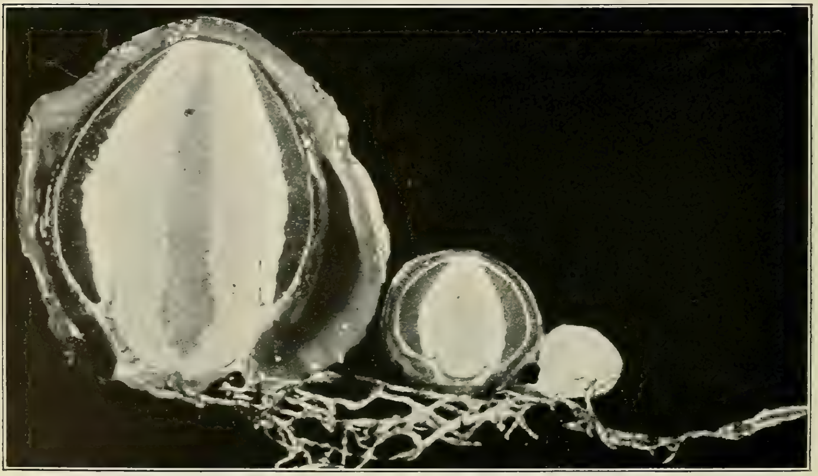

FIG. 3.—EGGS OF DICTYOPHORA RAVENELII.

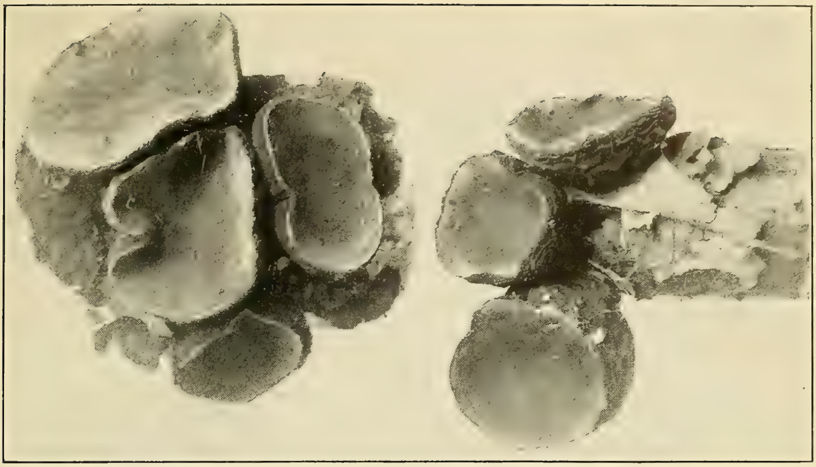

FIG. 1.—BULGARIA INQUINANS.

FIG. 2.—ITHYPHALLUS IMPUDICUS.

FIG. 1.—LEOTIA LUBRICA.

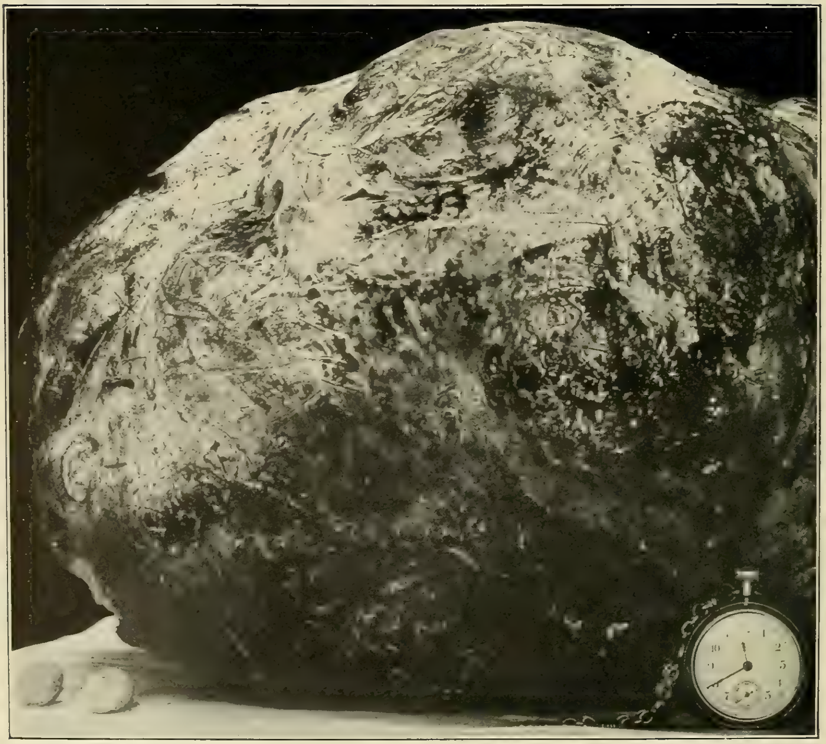

FIG. 2.—CALVATIA GIGANTEA. (EDIBLE.)

Peridium without a sterile base:
- Dehiscence apical or irregular.................................Bovista.
- Dehiscence basal, mouth visible only after rupture of outer peridium.................................Catastoma.

Peridium (outer) splitting into stellate segments.....................Geaster.

LYCOPERDON.

Species of the genus Lycoperdon are small puffballs with a somewhat thickened base and fibrous rooting mycelium. The peridium consists of two layers. The outer, the cortex, breaks up into small, soft scales, spines, warts, or granules which may soon disappear; the inner, the true peridium, is smooth, thin, and membranaceous, and opens by an apical mouth. When young the interior of the plants is white, soft, and firm; as they become old it changes to yellow and finally forms a purplish brown, dusty mass, composed of spores intermingled with threadlike filaments known as the capillitium. A central columella may be formed by a portion of the capillitium which extends into the upper part of the plant.

All the species of this genus are considered edible if collected while the interior is firm and white; the flavor, however, is inferior to that of large puffballs. Species of Lycoperdon are common on the ground or on old stumps or logs, generally clustered, and appearing in the summer and autumn.

Lycoperdon gemmatum. (Edible.)

Plants top shaped or with a subglobose head on a stout, cylindrical base, white, becoming gray or grayish brown; outer wall, the cortex, consisting of long pointed spines each surrounded by a ring of minute warts. The spines fall away, leaving scars on the inner layer of the peridium. The sterile portion usually occupies more than half the interior of the plant. The spore mass is greenish yellow to pale olive brown. The plant is 1 to 2 inches in height and 1 to $1\frac{1}{2}$ inches in diameter.

This species appears on lawns and is common on the ground in woods.

Lycoperdon pyriforme. (Edible.)

Plants obovate, pear shaped or subglobose, dingy white or brown; cortex of minute, persistent warts or scales, inner coat smooth; sessile or with a short stemlike base and with white rootlike fibers; columella present; capillitium and spores greenish, yellow, then olivaceous. The plants are 1 to 2 inches in height and about 1 inch in diameter. (Pl. XXXIV, fig. 1.)

A very common species, appearing in dense clusters on rotten stumps or logs.

CALVATIA.

The genus Calvatia contains puffballs of the largest size. It differs from Lycoperdon in the absence of an apical mouth and a regular method of dehiscence. The plants are terrestrial, globose, or top shaped, usually with a thick, cordlike, rooting mycelium. The cortex is thin, smooth, or covered with minute squamules.

The most delicious species of puffballs belong to this genus, but as in all fungi of this class, they must be eaten while the interior is perfectly white. If old they are disagreeable and indigestible.

Calvatia cyathiformis. (Edible.)

Plant globose or turbinate and depressed above, with a thick, somewhat stemlike base and cordlike root; cortex whitish gray or brown, sometimes with a pinkish purple tinge, thin, fragile, areolate in the upper part, which, after maturity, soon breaks up and falls away, leaving a cup-shaped base with a ragged margin attached to the ground; the capillitium and spores are at first violet, becoming dark purple-brown. The plant is 3 to 6 inches in diameter.

Common on open grassy ground in pastures, fields, and lawns; edible and of fine flavor.

Calvatia gigantea. Giant puffball. (Edible.)

Plant globose or obovoid, nearly sessile; plicate at base with cordlike mycelial strands. Cortex at first white and smooth, becoming yellowish or brown, sometimes slightly roughened by minute warts or sometimes cracking in areas; inner peridium thin and fragile; capillitium and spores when mature yellowish green to dingy olive.

The plants are generally 10 to 20 inches in diameter. Individuals of this species often attain an enormous size, the specimen shown in the accompanying illustration measuring 5 feet 1 inch in circumference. (Pl. XXXVIII, fig. 2.)

An excellent edible species, cosmopolitan and abundant, growing on lawns, pastures, and meadows.

BOVISTA.

Species of the genus Bovista are globoid, the peridium consisting of two walls: The outer, the exoperidium, thin, smooth, friable, having mostly disappeared at maturity; the inner, the endoperidium, thin, parchmentlike, opening irregularly or by an apical mouth; capillitium consisting of branched, short, free threads.

This genus may be distinguished from Lycoperdon by the absence of a sterile base, by the easy separation from place of attachment, and by the fragile exoperidium, which soon disappears, except perhaps at the base. Owing to the spherical form of these plants and their tendency to break away from the point of attachment they are readily blown about and on this account are called "tumblers."

Bovista pila. (Edible.)

Plants globose or obovoid, sessile, without a thickened base; exoperidium thin, at first white, becoming brown, and breaking away in fragments toward maturity; inner peridium tough, smooth, shining, brown or purplish brown, with age becoming silvery gray, dehiscent by an irregular torn mouth at or near the apex; mass of spores and capillitium pale brown or olivaceous, becoming dark or purple brown. The plants are 1½ to 2½ inches in diameter.

"This Bovista is remarkably tough; it maintains its shape firmly and persists a long time; it breaks away from its root and rolls about over the old leaves before the wind even till the following season." (*Morgan, vol. 14, p. 145.*)

CATASTOMA.

Species of the genus Catastoma are thus described: "Puffballs growing just beneath the surface of the ground and connected immediately with it by filamentous threads, which issue from every part of the cortex; after maturity, when the peridium breaks away, the lower part of the outer coat is held fast by the soil, while the upper

portion which has attained the surface remains, covering the inner peridium like a cap or inverted cup; consequently, the apparent apex at which the mouth is situated is the actual base of the plant as it grows. The capillitium threads are similar to the densely interwoven hyphæ, which form the inner peridium and are evidently branches of them radiating from the interior." (*Morgan, vol. 14, p. 142.*)

Catastoma circumscissum.

Peridium subglobose, more or less depressed, and often quite irregular; cortex thickish, fragile, usually rough and uneven from the adhering soil, after maturity torn away, leaving the lower two-thirds or more in the ground; inner peridium depressed-globose, subcoriaceous, rather thin, pallid, becoming gray, minutely furfuraceous, with a small regular basal mouth. Mass of spores and capillitium soft, compact, then friable, olivaceous, changing to pale brown (fig. 1; from Morgan).

GEASTER (EARTH STARS).

In the genus Geaster the peridium consists of three persistent coats. The two outer coats generally adhere and form the thick, fleshy-coriaceous exoperidium, which at maturity splits from the apex into several segments; the inner coat, the endoperidium, is more or less parchmentlike, either sessile or short stalked, and opens by an apical mouth. The spores are usually dark brown and mixed with capillitium.

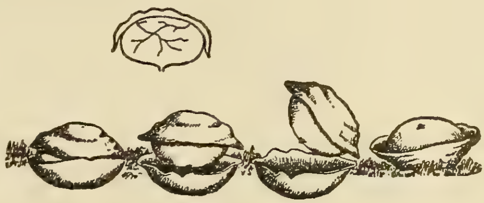

FIG. 1.—*Catastoma circumscissum*, showing method of growth, early and late stages. The cross section (at top) shows the origin of the threads of the capillitium. (After Morgan.)

The distinctive character of this genus is the stellate manner of dehiscence of the two outer layers. The segments thus formed vary from spreading, inrolled, or recurved to arched. The accompanying illustration (Pl. XXXVI, fig. 1) shows a form of the latter type in which the two layers of the exoperidium separate, the outer remaining as a segmented basal cup, while the inner layer becomes arched and causes the elevation of the endoperidium.

Geaster hygrometricus.

Peridium depressed globose; exoperidium splitting at the apex divides into a variable number of strongly hygrometric segments, which are rigidly inrolled when dry and expanded when moist; endoperidium whitish gray or brown, thin, membranaceous, with a small, irregular mouth.

Inner peridium three-fourths to 1 inch in diameter. Segments 6 to 20 in number, 2 to 3 inches in diameter when expanded.

Geaster hygrometricus is the species most frequently collected. It is common in woods, sandy locations, or partially cleared land. The peculiarity of this species is the hygroscopic nature of the exoperidium. In dry weather the segments are strongly recurved, but in wet weather they expand. This process may occur repeatedly, depending on weather conditions, and it is often called the "poor man's weather glass."

SCLERODERMACEÆ.

Fungi belonging to the family Sclerodermaceæ are developed at the surface of the ground. The peridium is generally thick, rough, warty, or scaly, but not composed of distinct layers. The representative genus of the family and the one most commonly observed by the amateur collector is Scleroderma.

SCLERODERMA.

In the genus Scleroderma the plants are sessile or nearly so. The peridial wall is generally thick, hard, and leathery, but it may be scaly or warty, indehiscent, or it may burst at the apex into stellate lobes. None of the species here described are highly recommended for edibility.

Scleroderma geaster.

Peridium mostly sessile, subglobose, coarse in texture, finally scaly, at length dehiscing in an irregularly stellate manner. These plants are at first dingy ocher in color, later becoming brown, the spore mass finally purplish brown. Specimens may be found from 2 to 3 inches in diameter. After dehiscence they often measure 4 to 5 inches across.

They are ordinarily found in sandy woods, banks, or bordering roadsides.

Scleroderma vulgare.

Peridium subsessile, subglobose, yellowish or pale brown, scaly or warty, plicate toward the base; spore mass purplish black.

Peridium 1 to 3 inches in diameter.

This species is very common and plentiful and is found in dry situations, on hard ground, along cinder paths and gravel walks.

A fungus nearly related to *Scleroderma vulgare*, considered by some authorities merely a variety, by others as a distinct species, is known as *Scleroderma verrucosum*. It differs from *S. vulgare* in possessing a thinner and more or less minutely warted peridium, in the umber color of the spore mass, and in the more pronounced stemlike development of the base.

NIDULARIACEÆ (bird's-nest fungi).

Members of the family Nidulariaceæ are represented by small, leathery, cup-shaped plants growing on old sacking, manure, earth, and decaying or dried wood. The common name is suggested by the form of the peridium, which is cup shaped and contains many small, lenticular bodies (peridiola) resembling eggs. The mouth of the peridium is at first covered by a membrane, which later becomes ruptured and exposes the sporangioles. The spore-bearing tissue and spores are never resolved into a dusty mass, as in many Gasteromycetes, but persist in the form of peridiola which contain the spores.

Key to Nidulariaceæ.

Peridium with several to many sporangioles:

  Peridium torn at the apex in opening—

    Sporangioles not attached to the inner wall of the peridium..... NIDULARIA.

Peridium with several to many sporangioles—Continued.
Peridium opening by a deciduous membrane—
Sporangioles attached to the inner wall of the peridium—
Peridium of three united layers and spores mixed with filaments.. CYATHUS.
Peridium of a single layer and spores not mixed with filaments.. CRUCIBULUM.

CYATHUS.

In Cyathus the peridium is cuplike and composed of three layers. The apex is covered by a white membrane, which bursts, disclosing egglike bodies, the peridiola, which usually fill about one-half of the cup. The peridiola are attached to the inner wall of the peridium by an elastic cord, which is attached to each peridiolum in a depression on one side.

Cyathus stercoreus.

Peridium cylindrical, campanulate to infundibuliform, sessile or with an elongated base, light brownish, at first with shaggy, matted hairs which disappear in age, interior smooth and nonstriate; peridiola black.

Cyathus stercoreus is an exceedingly common species and is to be found growing on manure or in heavily manured places. It is subject to considerable variation in size and form.

Cyathus striatus.

Peridium obconic, exterior even, brownish, hairy, interior striate, lead colored; apex truncate, covered by a white membrane, which is at first strigose; peridiola compressed, subcircular.

Plant one-half to three-fourths inch in height and about three-eighths inch in diameter.

Cyathus vernicosus.

Peridium bell shaped, subsessile, base narrow, broadly open above, exterior at first brownish, silky tomentose, becoming smooth, interior dull lead color, smooth. Differs from *Cyathus striatus* in the even, nonfluted inner surface of the peridium and in the larger peridiola.

Plant about one-half inch in height and about three-eighths inch in diameter.

CRUCIBULUM.

In Crucibulum the peridium is cup shaped and consists of one thick fibrous layer, lined by a very thin, smooth, and shining layer. The mouth when young is covered with a yellowish tomentose membrane, the peridiola are more numerous than in the preceding genus, and each is attached to the peridium by an elastic cord which springs from a projection on the peridiolum. The plants are smaller than in the genus Cyathus.

Crucibulum vulgare.

Peridium yellowish brown, becoming paler with age, outer surface when young velvety tomentose, inner surface smooth and shining; mouth at first closed by a yellowish membrane, which ruptures and exposes the peridiola. Peridiola biconcave, with a projection on one side from which originates the elastic cord which attaches the peridiola to the peridium.

Plant about one-fourth inch in height and about the same in diameter.

ASCOMYCETES.

The character peculiar to all fungi of the class known as Ascomycetes is the production of spores in asci, microscopic saclike bodies instead of gills, tubes, teeth, or other specially modified structures. The genera are subject to great variation in form, size, and consistency. The plants may be spherical, elongated, expanded or cup shaped, sessile or stipitate, microscopic or several inches in size, waxy or gelatinous, hard or soft, elastic or rigid. The genera described here may be identified by the assistance of the accompanying key, which does not require a consideration of microscopic characters.

Key to Ascomycetes.

Plants cup shaped to disk shaped, gelatinous, fleshy:
Substipitate, closed at first, large, exterior rough, interior gelatinous-pulpy........ BULGARIA.
Plants stipitate, hymenophore clavate, globose or conical, deeply folded and pitted........ MORCHELLA.
Plants stipitate, hymenophore irregular or lobed, with conspicuous brain-like convolutions, hollow........ GYROMITRA.
Plants capitate, stem cylindrical or laterally compressed, gelatinous-gristly, hymenophore undulated or even........ LEOTIA.
Plants stipitate, urn shaped, leathery, blackish........ URNULA.

BULGARIA.

In the genus Bulgaria the plants are cup shaped, sessile, or substipitate and are either single or gregarious. They are of a pulpy gelatinous consistency when fresh or in wet weather, but horny to cartilaginous when dry. The two species most frequently encountered by the collector are *Bulgaria inquinans* and *B. rufa*, both of which grow on dead branches or fallen twigs.

The cups of *Bulgaria rufa* are subturbinate, at first closed, later concave, the margin wavy when old, hymenium light colored, plants 1 to 2 inches in diameter. *Bulgaria inquinans* may be distinguished from *B. rufa* by the more uniform turbinate caps, dark hymenium, and smaller size. (Pl. XXXVII, fig. 1.)

MORCHELLA.

The genus Morchella is very easily distinguished by the prominently ridged and pitted hymenium (cap), which is hollow and continuous with the cavity of the stem, to which it is adnate throughout its length. The plants are stipitate, waxy, and brittle in consistency, and the caps are conic or cylindrical to ovate.

From early historic times the morels have been considered among the choicest edible fungi.

Morchella esculenta. (Edible.)

The species of most common occurrence is *Morchella esculenta*. The plants are from 2 to 4 inches high and about 1½ to 2 inches broad; the cap is ovate or oblong, deeply pitted, dingy yellow, tawny, or greenish; the stem is 1 to 2 inches long, stout, generally hollow, whitish. This species is of wide and abundant occurrence and is found on the ground, particularly along banks of streams or in sandy localities. (Pl. XXXV, fig. 2.)

GYROMITRA.

The genus Gyromitra is distinguished from Morchella by the thick brainlike folds of the hymenophore, as contrasted with the irregular polygonal depressions or pits in Morchella, and from Helvella by the hymenophore being basally attached to the stem, while in Helvella the cap is always free.

Gyromitra esculenta.

The species is stipitate, the hymenium inflated, gyrose, undulated, hollow, or cavernous, margin attached to the stem, brownish red. This species is generally 2 to 4 inches high and 2 to 3 inches broad, although much larger specimens are often found. The plants appear in May and June and show a preference for a sandy habitat in coniferous woods. They are much more abundant in moist or wet seasons. By many authorities *Gyromitra esculenta* is considered a very excellent edible species, but there are reports of its producing cases of poisoning, and because of the uncertainty we would not class it with the edible species.

LEOTIA.

The interesting little stipitate genus Leotia comprises plants commonly found on rotten wood, moss, along streams or on moist ground, gregarious or in clusters. The cap is irregularly orbicular, supported in the center, and revolute at the margin. Two species, *Leotia chlorocephala* and *L. lubrica*, are of frequent occurrence. Both forms are somewhat gelatinous, but in *L. chlorocephala* the cap is dark green and the stem green and twisted, while in *L. lubrica* the cap is yellowish green and the stem yellow, nearly equal, or inflated at the base and finally hollow. These plants grow from 1½ to 3 inches high. (Pl. XXXVIII, fig. 1; from W. A. Kellerman.)

URNULA.

Urnula craterium.

This species is commonly known as the black-urn fungus, a designation descriptive of its shape. The plants are about 1½ to somewhat over 2 inches in width and 2 to 3 inches in height, dark brown to black, irregularly hemispherical to urn shaped, opening by a stellate rupture, margin incurved, leathery or cheesy in consistency, covered externally with minute black hairs. The stem is stout, sometimes grooved, the same color as the cap, and hairy. Specimens are generally found on half-buried sticks or branches. (Pl. XIII, fig. 2.)

POISONOUS OR SUSPECTED MUSHROOMS.

The following species are poisonous or suspected of being poisonous:

Amanita chlorinosma.
Amanita cothurnata.
Amanita junquillea.
Amanita muscaria.
Amanita pantherina.
Amanita phalloides.
Amanita porphyria.
Amanita radicata.
Amanita solitaria.
Amanita spreta.
Amanita strobiliformis.
Amanita virosa.
Amanitopsis volvata.
Boletus erythropus.
Boletus felleus.
Boletus luridus.
Boletus miniato-olivaceus *var.* sensibilis.
Boletus satanus.
Calvatia cyathiformis.
Cantharellus aurantiacus.
Clathrus columnatus.
Clavaria aurea.
Clitocybe geotropa.
Clitocybe illudens.
Cortinarius purpurascens.
Elaphomyces granulatus.
Entoloma grande.
Entoloma lividum.
Entoloma sinuatum.
Entoloma speculum.
Geaster hygrometricus.
Gyromitra esculenta.
Hebeloma crustuliniforme.
Hebeloma fastibile.
Helvella esculenta.
Hypholoma fasciculare.
Hygrophorus conicus.
Inocybe infelix.
Inocybe infida.
Ithyphallus impudicus.
Lactarius fuliginosus.
Lactarius piperatus.
Lactarius pyrogalus.
Lactarius rufus.
Lactarius theiogalus.
Lactarius torminosus.
Lactarius villereus.
Lactarius zonarius.
Lepiota dolichaula.
Lepiota morgani.
Marasmius peronatus.
Marasmius urens.
Mitrula paludosa.
Panaeolus campanulatus.
Panus papilionaceus.
Panus stypticus.
Pholiota autumnalis.
Pleurotus olearius.
Psilocybe foenisecii.
Russula emetica.
Russula foetens.
Russula fragilis.
Russula nigricans.
Russula nitida.
Russula queletii.
Scleroderma bovista.
Stropharia aeruginosa.
Stropharia semiglobata.
Tricholoma sulphureum.
Tricholoma tigrinum.
Tricholoma venenatum.
Volvaria gloiocephala.

GLOSSARY.

Ad′nate, closely attached, as gills to stipe.

Adnexed′, gills reaching the stem but not adnate to it.

Anas′tomosing, united by running together irregularly, as of gills or veins with each other.

An′nulate, having a ring.

An′nulus, the ring on the stem of a mushroom formed by the separation of the veil from the margin of the cap.

A′pex, in mushrooms, the extremity of the stem nearest the gills.

Ap′ical, relating to the apex or top.

Appendic′ulate, having an appendage hanging in small fragments.

Arach′noid, cobweblike.

Are′olate, divided into little areas or patches.

Ascend′ing, rising somewhat obliquely upward or curving.

As′ci, plural of ascus.

Ascomyce′tes, group of fungi in which the spores are produced in saclike cells called asci.

As′cus, microscopic sacklike cell in which spores, generally eight, are developed.

At′omate, sprinkled with minute particles.

Atten′uate, becoming gradually narrowed or smaller.

Ax′is, the central line of growth, stipe, stalk, etc.

Azo′nate, without zones or circular bands of different color.

Basid′ium, an enlarged cell upon which spores are borne.

Basid′iomyce′tes, a group of fungi which has its spores produced upon basidia.

Bifur′cated, divided into two forks or branches.

Bul′bous, applied to stem of a mushroom with bulblike swelling at the base.

Campan′ulate, bell shaped.

Car′nose, fleshy.

Cartilag′inous, gristly, firm, and tough.

Cen′timeter (cm.) the hundredth part of a meter, equal to 0.3937 of an inch.

Ces′pitose, growing in tufts or clumps.
Cla′vate, club shaped.
Co′mate, hairy.
Coria′ceous, of a leathery texture.
Cor′neous, of a horny texture.
Cor′rugated, having a wrinkled appearance.
Cor′tex, an outer rindlike layer.
Cre′nate, notched at the edge, notches blunt, not sharp as in a serrated edge.
Cu′ticle, skinlike layer on the outer surface of cap and stem.
Cyath′iform, cup shaped.
Decid′uous, falling off at maturity.
Decur′rent, applied to gills which are prolonged down the stem.
Deliques′cent, relating to mushrooms which become liquid.
Den′tate, toothed.
Dimor′phic, existing in two distinct forms.
Dis′coid, disk shaped, of a circular, flat form.
Dis′tant, applied to gills which are not close.
Divar′icate, diverging widely.
Eccen′tric, same as excentric.
Echin′ulate, beset with short bristles.
Emar′ginate, when gills are notched or scooped out at junction with stem.
Excen′tric, not central.
Exoperid′ium, outer layer of the peridium.
Expan′ded, spread out, as the pileus (cap) from convex to plane.
Farina′ceous, mealy.
Far′inose, covered with a white, mealy powder.
Fi′brillose, appearing to be covered or composed of minute fibers.
Fi′brous, clothed with small fibers.
Fim′briate, fringed.
Fis′sured, cleft or split.
Flabel′liform, fan shaped.
Floc′cose, downy, woolly.
Fo′veolate, marked with minute pits or depressions.
Free, said of gills not attached to the stem.
Fur′cate, forked.
Gibbous, swollen at one side.
Gla′brous, smooth.
Gleba, spore-bearing tissue in Gastromycetes.
Gran′ular, covered with or composed of granules.
Grega′rious, growing together in numbers in the same locality.
Gut′tula, a small drop or droplike particle.
Hab′itat, natural place of growth of a plant.
Hirsute′, hairy with stiff hairs.
Hoar′y, covered with short, dense, grayish-white hairs.
Hygromet′ric, readily absorbing and retaining moisture.
Hygroph′anous, watery when moist, opaque when dry.
Hyme′nium, the fruit-bearing surface.
Im′bricate, overlapping like shingles.
Immar′ginate, without a well-defined margin.
Incised′, having marginal slits or notches.
Indu′sium, in phalloids, a veil hanging beneath the pileus (cap).
Inflexed′, bent inward.
Infundib′uliform, funnel shaped.
In′nate, adhering by growth.
In′volute, rolled inward.
Lac′cate, as if varnished or coated with wax.
Lacin′iate, cut into jagged edges.
Lan′ceolate, tapering to both ends.
La′tex, thick, milky juice.
Lactif′erous, applied to tubes containing latex.
Line, one-twelfth of an inch.
Mac′ulate, spotted.
Mar′ginate, having a well-defined border.
Ma′trix, the substance upon or in which a fungus grows.
Mi′cron, one one-thousandth of a millimeter, represented by the Greek letter mu (μ) following the number.
Mil′limeter (mm.) the thousandth part of a meter, nearly one twenty-fifth of an inch; 25.4 mm. = 1 inch.
Mu′ricate, rough, with short, hard points.
Obo′vate, broad end upward or toward the apex.
Paraph′yses, slender threadlike structures growing with the asci.
Par′tial, said of a veil clothing the stem and reaching to the edge of the cap but not extending beyond it.
Pec′tinate, toothed like a comb.

Pel′licle, a thin skin.
Perid′ium, the coat of certain plants, as for example, puffballs; may be single or double.
Pi′leate, having a cap or pileus.
Pi′leus, cap of a fungus.
Pi′lose, covered with hairs; furry.
Pli′cate, folded like a fan.
Pi′lei, plural of pileus.
Plane, applied to gills with even edge.
Plu′mose, feathery.
Po′roid, porelike.
Pru′inose, covered with a bloom or powder.
Pubes′cent, covered with soft, short hairs, downy.
Pul′vinate, cushion shaped.
Punc′tate, dotted with points.
Reflexed′, turned back.
Resu′pinate, attached to the matrix by the back, the hymenium facing outward.
Retic′ulate, marked with cross lines like the meshes of a net.
Rev′olute, rolled backward or upward.
Rhi′zomorphs, long, branching or anastomosing, rootlike cords of mycelium produced by many fungi.
Rim′ulose, covered with little cracks.
Ring, annulus, a part of the veil adhering in the form of a ring to the stem of an agaric.
Ri′vose, marked with furrows which do not run in parallel directions.
Ru′gose, wrinkled.
Sap′id, agreeable to the taste.
Sca′brous, rough on the surface.
Sca′riose, thin, dry, membranaceous; applied to a shriveled membrane.
Sclero′tium, a hard, compact mass of mycelium, the resting stage of certain fungi.
Scrobic′ulate, marked with small pits.
Se′riate, arranged in rows.
Seri′ceous, silky.
Ser′rate, saw toothed.
Se′tose, bristly.
Sin′uate, wavy, as the margin of gills.
Si′nus, a rounded inward curve.
Spor′ophore, the fruiting body of a fungus.
Squa′mous, covered with appressed scales.
Stipe, stem of a mushroom.
Stri′ate, marked with parallel or radiating lines.
Stri′gose, rough with stiff hairs.
Stuffed, said of a stem filled with material of a different texture from its walls.
Sul′cate, grooved, marked with furrows.
Tes′sellated, checkered in a regular manner.
Tomen′tose, densely pubescent with matted wool.
Trun′cate, cut squarely off.
Tu′bercle, wartlike excrescence.
Tur′binate, top shaped; an inverted cone.
Umbil′icate, with a central depression.
Um′bo, central elevation.
Un′cinate, hooked; forming a hook.
Un′dulate, wavy.
Univer′sal, said of the veil or volva which entirely envelopes the fungus when young.
Vag′inate, sheathed.
Ve′nate, veined, intersected by swollen wrinkles below and on the sides.
Ven′tricose, swollen in the middle.
Ver′nicose, appearing as if varnished.
Vil′lose, covered with long, weak hairs.
Vis′cid, moist and sticky.
Vis′cous, gluey.
Zo′nate, marked with concentric bands of color.

RECIPES FOR COOKING MUSHROOMS.

According to the views of many persons, mushrooms are best cooked simply, with butter, pepper, and salt only for seasoning. The addition of various condiments impairs the delicate mushroom flavor. However, tastes vary, and the opportunity of choice or experiment is herewith rendered available by selections which may be made from the recipes which follow. All have been either tried

by the writers or selected from the printed directions of capable authorities.

The general statement can be made that mushrooms may be prepared for the table in any way which would be suitable for oysters.

The caps should be carefully washed, gill side down; peeling may be required to remove adherent foreign matter, but otherwise it is unnecessary and involves a considerable waste of time and loss of flavor. Unless they are extremely tough, the stems should not be discarded, but cut into small bits and stewed, or, after long boiling, even if tough, run through a sieve and made into a soup or sauce.

Wild mushrooms should be cooked soon after collection, as they are in that way much better preserved than if kept uncooked, even in a refrigerator.

Some thin, juicy, wild varieties, as species of Coprinus, may require cooking but 5 to 10 minutes, while thicker, tough plants may require 30 to 40 minutes, and some mushrooms which never become tender by stewing may be excellent if fried. Judgment, a most essential qualification for a good cook, will usually assist in the selection of a method suited to the species in hand and in deciding the length of time necessary for its cooking.

Deviled Mushrooms.

Chop or break into small pieces 1 quart of mushrooms seasoned with pepper and salt; prepare 1 pint of bread crumbs; mix the mashed yolks of 2 hard-boiled eggs with 2 raw ones and stir into 1 cup of milk or cream. Put a layer of crumbs in the bottom of a baking pan or dish, then a layer of mushrooms, scatter over bits of butter, pour on a part of the cream and egg mixture, and continue until the dish is full, having bread crumbs with butter for the top layer. Closely covered, bake 20 minutes in a hot oven; then uncover for about 5 minutes, or sufficiently long for the top to be well browned. If preferred, water and lemon juice may be substituted for milk or cream.

Fried Mushrooms.

Beat the yolk of an egg with a tablespoonful of water, and season with pepper and salt. In this, dip each cap and then dip into fine cracker crumbs or corn meal. Have butter or cooking oil very hot in a frying pan. Fry slowly on each side 5 minutes. A sauce can be made by thickening the butter or oil with flour and adding milk or cream. If desired, serve on toast. A smooth, thin tomato sauce is also excellent.

Fricasseed Mushrooms.

Peel and remove the stems from large mushrooms. Make a forcemeat by chopping the white meat of a cold roast chicken fine with a few small mushrooms and moistening it with chicken stock. Grease a pudding dish and lay the large mushrooms, tops down, in this. Fill the mushrooms and the space between them with the forcemeat. Sprinkle bits of butter over all. Pour in enough of the chicken stock to make the contents of the dish very moist, lay a few waferlike slices of bacon on top of the scallop, and bake, covered, in a hot oven for 15 minutes; uncover, and cook for 5 minutes longer. Serve in the dish in which they were cooked. (*Marion Harland's Cookbook, p. 460.*)

Baked Mushrooms.

Peel and stem large mushrooms. Line a deep baking dish with thin slices of toast, each of which has been dipped for an instant in seasoned beef stock. Fill the dish with layers of mushrooms, sprinkling each layer with salt, paprika, and bits of butter. When the dish is full, pour over all a gill of stock, and bake, covered, for 20 minutes; uncover, and cook for 5 minutes before sending to the table. (*Marion Harland's Cookbook, p. 213.*)

Broiled Sweetbreads with Mushrooms.

Blanch the sweetbreads and cut them in half, lengthwise. Grease a small gridiron, lay the split sweetbreads on this, and broil over a clear fire, turning frequently and watching carefully lest they scorch. When done, lay on rounds of crustless toast, rub thoroughly with butter; salt and pepper to taste and cover with minced mushrooms fried in butter. (*Marion Harland's Cookbook, p. 121.*)

Oysters with Mushrooms.

Drain about 25 oysters, put them into a hot pan with a teaspoonful of butter and toss them until they are plumped and ruffled on both sides. Then place them in a hot dish. To the oyster liquor add the juice of half a pint of chopped mushrooms and enough milk to make a pint. Thicken this with a tablespoonful of flour moistened with a little milk and cook 3 minutes; stir in the mushrooms and cook 2 minutes longer; add a half teaspoonful of salt, a half teaspoonful of lemon juice, a teaspoonful of onion juice, the beaten yolks of 2 eggs, and a heaping tablespoonful of butter. Put in the oysters and as soon as the preparation reaches the boiling point turn into a hot dish. (*Marion Harland's Cookbook, p. 150.*)

Mushrooms with Bacon.

Fry the bacon, and on removing it from the frying pan keep hot; cook the mushrooms on each side in the "fryings"; serve on a platter with the strips of bacon arranged as a border.

Several species are good prepared in this manner, but it is one especially well suited to *Agaricus campestris.*

Mushrooms Baked with Tomatoes.

In a baking dish arrange small round slices of buttered toast; upon each piece place a rather thin slice of peeled tomato, salted and peppered; upon each slice of tomato place a fine, thick mushroom, gill side up; in the center of each mushroom put a generous piece of butter; season with pepper and salt. Cover the dish and bake in a hot oven 10 minutes; then uncover and bake for an additional 5 to 10 minutes, as the mushrooms appear to require.

Peppers Stuffed with Mushrooms.

Cut the stem end of the peppers and carefully remove all seeds and the white membrane; chop or break the mushrooms into small pieces, season with pepper and salt, press firmly into the peppers, and put a good-sized lump of butter on top of each. The water adhering to the mushrooms after washing will furnish sufficient moisture for their cooking. Arrange the peppers on end in a baking dish, having water with salt, pepper, and butter poured into the depth of about an inch. Place the dish in a hot oven, cook covered 15 minutes; then uncover and baste and cook for 10 to 15 minutes longer, or until the peppers are perfectly tender. An addition of chopped cooked chicken or veal to the mushrooms is a pleasing variation.

Mushrooms and Cheese.

Butter a baking dish, place in layers mushrooms broken in small pieces, bread crumbs, grated cheese, salt, pepper, and bits of butter; continue until dish is filled, letting the top layer be a thin sprinkling of cheese. Cover and cook in oven for 20 minutes; remove cover for 5 minutes before serving.

Mushrooms à la Poulette.

Stew the mushrooms in cream; remove from the fire and stir in the beaten yolks of two eggs. Return to the fire to let the eggs thicken; then serve at once. (*Helen Cramp. Universal Cookbook*, p. 172.)

Mushroom Pie.

Various species are good prepared in the form of pie. Ordinary pastry crust may be used or a rich biscuit dough is well adapted for the purpose. The mushrooms should be previously stewed, and to the liquor should be added milk or cream, a little thickening, butter, pepper, and salt.

Cream of Mushroom Soup.

Stew caps and stems cut in small pieces for an hour or longer; run through a colander, add cream or milk, thicken with flour, add butter, salt, and pepper. Pour in bouillon cups and serve with whipped cream on top.

Salads.

For salads many mushrooms can be used raw (after being peeled), especially species of Coprinus and Clavaria and all puffballs. Tougher plants can be stewed, drained, and chilled before adding the dressing, which may be either a mayonnaise or French dressing of oil with vinegar or lemon juice. Serve on lettuce.

Mushroom Patties.

Cut the mushrooms into small pieces, cook slowly in butter until tender, add cream or milk, pepper, and salt, and thicken with flour. Fill the reheated patty shells.

Under the Glass Cover, or Bell, with Cream.

With a small biscuit cutter, cut rounds from slices of bread; they should be about 2½ inches in diameter and about half an inch in thickness. Cut the stems close to the gills from fresh mushrooms; wash and wipe the mushrooms. Put a tablespoonful of butter in a saucepan; when hot, throw in the mushrooms, skin side down; cook just a moment, and sprinkle with salt and pepper. After the rounds of bread have been slightly toasted, arrange them in the bottom of a bell dish and heap the mushrooms on them; put a little piece of butter in the center; cover over the bell, which is either of glass, china, or silver; stand them in a baking pan, and then in the oven for 20 minutes. While these are cooking, mix a tablespoonful of butter and one of flour in a saucepan, add either a half pint of milk or a gill of milk and a gill of chicken stock; stir until it boils, then add a half teaspoonful of salt and a dash of pepper. When the mushrooms have been in the oven the allotted time, bring them out; lift the cover, pour over quickly a little of this sauce, cover again, and send them at once to the table.

Mushrooms in Paper Bags.

Cut the stems close, sprinkle lightly with salt, and lay in a well-greased bag together with a big teaspoonful of butter rolled in flour and half a cupful of rich cream. Seal and cook 12 minutes in a hot oven. (*Emma Paddock Telford. Standard Paper-Bag Cookery, p. 93.*)

Suggestions for Certain Species.

ARMILLARIA MELLEA.

While not one of the best edible species, it is excellent fried and served on toast and also is quite good stewed.

CANTHARELLUS CIBARIUS (CHANTERELLE STEW).

This mushroom, being of rather tough consistency, requires long and slow cooking. "Cut the mushrooms across and remove the stems; put them into a closely covered saucepan, with a little fresh butter, and sweat them until tender at the lowest possible temperature. A great heat always destroys the flavor."—*Mrs. Hussey.* (*W. Hamilton Gibson. Our Edible Toadstools and Mushrooms and How to Distinguish Them, p. 310.*)

COPRINUS.

Species of Coprinus are very delicate, and *Coprinus micaceus* is considered the most digestible of all mushrooms. They are good steamed 5 minutes and served with butter and white sauce.

Species of Coprinus are also delicious baked with cheese. Butter a baking dish and put in a layer of mushrooms, bread crumbs, cheese grated (or cut in small pieces), and season with pepper and salt. Repeat the process once or twice according to the amount to be prepared, adding a few small lumps of butter to the last layer. Bake 15 to 20 minutes.

FISTULINA HEPATICA.

The beefsteak fungus should be sliced across the grain and soaked in salt water, the length of time varying probably with its age. The slices should be wiped dry and broiled or fried, then dressed with butter, salt, and pepper.

The fungus may be used raw for salad, dressed to suit the taste of the collector, stewed, or made into soup. The suggestion of its use as the foundation for a beefsteak pie is apparently worthy of experiment, as the resemblance to a good steak, in flavor if not in texture, is quite remarkable.

MARASMIUS OREADES.

The fairy-ring fungus is especially popular stewed and served with a brown sauce as an accompaniment to beefsteak. The species dries easily and even those dried naturally in the open may be revived by soaking and prepared for the table.

Fairy-ring pickles can be made after being packed in jars by having highly spiced vinegar heated to the scalding point poured over them. They are ready for the table in about two weeks.

MORCHELLA ESCULENTA.

All morels are delicious. Probably the best manner of preparing them is stuffed with a force meat made of chopped cooked chicken or veal, with moistened bread or cracker crumbs seasoned simply with salt and pepper. The stalks should be split to permit the stuffing, and then tied together before the morels are baked. In the covered baking dish there should be a very small quantity of water.

PLEUROTUS OSTREATUS (MOCK OYSTERS).

Take small specimens of *Pleurotus ostreatus* or cut from large tender ones pieces the size and shape of oysters. Dip them in the beaten yolk of an egg to which a tablespoonful of water has been added, and roll in cracker crumbs or corn meal. Season with salt and pepper. Fry in either deep fat, melted butter, or oil.

PUFFBALLS.

Never use puffballs unless the inner part is perfectly white when sliced. They should be peeled and can then be dressed raw for a salad, stewed with cream, and served either in patty shells, or on toast, or fried. When fried simply in melted butter or oil, they are fine; or the slices may be dipped in egg and cracker meal before being placed in the frying pan. A cream dressing is a delicious addition to fried puffballs.

TRICHOLOMA EQUESTRE.

This species is most excellent fried; also creamed and served as patties. A unique way of serving it is in a soup made with water, pepper, and salt, which will deceive any person into believing he is enjoying a dish of extremely fine turkey broth. After straining—for it must be a clear soup—add a small amount of butter.

TRICHOLOMA TERREUM.

Fine for patties and makes a most excellent soup, especially if celery is boiled with the chopped mushrooms; strain, and add butter, pepper, and salt.

Preserving Wild Mushrooms.

Requests for instructions in regard to canning mushrooms are frequently received. The following directions, compiled by the Office of Experiment Stations from Bulletin No. 98 of the Oregon Agricultural Experiment Station, describe methods of canning and drying alike applicable to cultivated or wild species. The author, E. F. Pernot, states that mushrooms "may be canned as easily as fruit and much easier than some vegetables."

The buttons ranging in size from the smallest to those with the cup breaking from the stem are the most desirable for canning, as they remain firm and white after being heated. When sufficient buttons are gathered they are cleaned by peeling or by wiping with a cloth, removing any soiled spots or earth which may have adhered to them. The stems are cut off, leaving from one-half to 1 inch attached to the cap. They may then be placed in a granite-iron kettle and heated without water until

shrinkage ceases, after which they are placed in cans that have previously been cleaned and scalded, and the liquor poured over them, completely filling the can.

If glass cans are used, after filling they are placed in any kind of vessel provided with a cover and containing a small quantity of hot water. A sheet of asbestos or a thin layer of excelsior is placed in the boiler to prevent the glass from coming in contact with the bottom. The caps are placed loosely on the cans and with steamer cover in place the water allowed to simmer for half an hour. Upon removing the cover from the steamer the can covers are immediately screwed down as tightly as possible; then the cans are put away to cool, upside down , in order to detect any leak. If all are perfectly sealed, allow them to stand until the next day at the same time, when they are again heated in the same manner, except that the time must be prolonged to one hour, because the contents of the cans are cold. Again the third day repeat this operation, which will complete the sterilization, and the mushrooms will be found to be as nearly like the fresh article as it is possible to have them. They keep well and do not deteriorate either in consistency or in flavor. The cans must be kept sealed throughout the operation.

If desired, the mushrooms may be stewed in milk or prepared in any manner for the table and then canned in the manner described. When the can is opened they require heating only before serving.

When tin cans are used they are handled in the same manner as glass ones, except that the lid should be soldered as soon as the can is filled, leaving the vent open until after heating the first time; then the vent should be immediately closed with a drop of solder while the can is hot, thus forming a partial vacuum that takes up the expansion caused by subsequent heatings.

Mushrooms in Oil.

After boiling for about 10 minutes, drain and pack the mushrooms in a jar, filling it with melted butter or oil. Seal and keep in a cool place.

Although this method seems expensive it in reality is not, because if the mushrooms are tightly packed the butter used will simply furnish the amount required for seasoning in their final preparation for the table.

Mushroom Catsup.

One pint mushroom liquor.
One-half ounce peppercorns.
One-fourth ounce allspice.
One-fourth ounce green ginger root.
One-fourth ounce cloves.
One blade mace; salt.

Wash and look over the mushrooms carefully; put them in an earthen jar with alternate layers of salt. Let stand for 24 hours in a comparatively warm place; put through a fruit press and add the ginger root cut into small pieces. Measure the liquor; add peppercorns and simmer for 40 minutes; then add the spices and boil for 15 minutes. Take from the fire and cool; strain through a cloth, bottle, and seal. (*Helen Cramp. Universal Cookbook, p. 387.*)

Place mushrooms in an earthen jar and sprinkle salt over them, stirring so that all receive the salt; allow them to stand for 12 hours; then mash and strain through a cloth. For every quart of the liquid add half a teaspoonful of ground ginger and half a teaspoonful of black pepper. Boil the liquid in a granite-iron kettle until it is reduced not less than one-third. Prepare the bottles by cleaning and thoroughly boiling them and their corks; then fill to the neck with hot catsup, cork tightly, and when the cork has dried and before they are cold, dip the cork and about half an inch of the bottle neck into hot canning wax, previously melted in a cup or can. It is advisable to use rather small-sized bottles, so that the contents may be used before remaining open too long. (*E. F. Pernot, Oregon Agricultural Experiment Station, Bulletin No. 98.*)

Dried Mushrooms.

A good use to make of the older mushrooms is to dry them. This may be done after they have been peeled or cleaned by placing them upon boards or drying racks, only one deep, and exposing them to the sun and air. Beginning with the cap side down, they should be turned over every day and must not be left out during the night, as they absorb moisture very rapidly. They may also be dried upon wooden trays in a warm room. When dried by either method until they feel dry to the touch finish them in the oven and while brittle grind them into a fine powder with a spice mill, or even a coffee mill will answer the purpose. The powder should at once be placed in well-stoppered, dry bottles, or fruit jars well sealed, and kept in a warm,

dry place. Mushrooms that are wet can not be successfully dried. The best are those which grow and are gathered dry.

Mushroom powder keeps very well, and it is one of the most delicious flavoring condiments of the kitchen. If milk is used in making meat gravy or other dishes the flavor is much more pronounced.

The mushrooms may also be dried in the manner described, and used whole by first soaking them before preparing the various dishes; they are practically the same as fresh ones, with the exception of being somewhat tough. The flavor is fully as strong as in fresh ones. (*E. F. Pernot, Oregon Agricultural Experiment Station, Bulletin No. 98.*)

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